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Les fichiers d'images tridimensionnelles du CNRC

M. Rioux et L. Cournoyer

Juin 1988

The NRCC Three-dimensional Image Data Files

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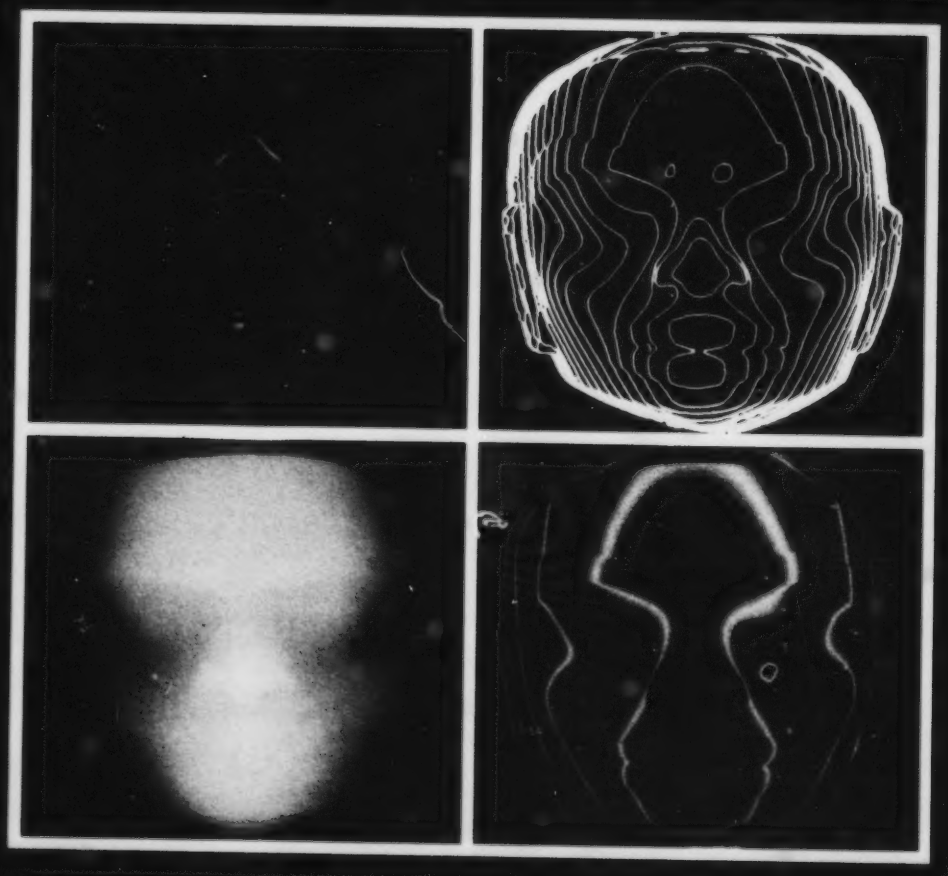

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LES FICHIERS D'IMAGES TRIDIMENSIONNELLES DU CNRC/
THE NRCC THREE-DIMENSIONAL IMAGE DATA FILES

M. Rioux et L. Cournoyer

CNRC n° 29077

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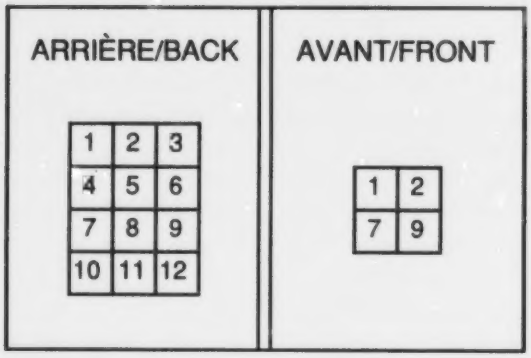

COUVERTURE

Les photographies de la page couverture nous montrent les différentes formes d'affichages à partir d'une seule acquisition tridimensionnelle (x, y, z, I). Les trois premières coordonnées représentent la position spatiale d'un élément de l'objet, tandis que I, l'autre coordonnée, est proportionnelle entre autres à sa réflectivité. Toutes les coordonnées obtenues à partir d'une acquisition nous sont montrées aux photographies 7 et 8. En 7, nous avons x, y, z. Les valeurs de z (élévation ou distance) sont codées en niveaux de gris. En 8 nous avons x, y, I et les valeurs de I qui sont en registre avec les valeurs de z sont proportionnelles à la réflectivité de l'objet dans la scène (essentiellement une photographie de la scène à la longueur d'onde du laser). Les données de distance et d'intensité peuvent être combinées ensemble dans une seule et même vue (telle qu'illustré en 11 et 12). Il s'agit d'une vue stéréoscopique (vue avant) générée à partir des données illustrées en 7 et en 8. Il est à noter qu'on peut ainsi générer des vues stéréoscopiques de dessus, de dessous ou même de côté en utilisant le même fichier de données (x, y, z, I). En 5

COVER

Cover photographs show various displays from a single three-dimensional acquisition (x, y, z, I). The first three coordinates are the spatial location of an object element and I, the other coordinate, is proportional among others to its reflectivity. All the coordinates obtained from one acquisition are displayed in photographs 7 and 8. In 7, we have x, y, z where z values (elevation or range) are grey level coded. In 8 we have x, y, I where values of I are registered to z values and proportional to the reflectance of the object in the scene (essentially a photograph of the scene at the laser wavelength). Range (z) and intensity (I) values can be combined as shown in 11 and 12. This is a front view stereo pair using data shown in 7 and 8. Note that a side view stereo pair as well as bottom and top views can be generated the same way using the same data file (x, y, z, I). On 5 and 6 we also display a stereo pair, this time using range (z) data only (no I values). The shading is made by taking a horizontal derivative of the data. This processing allows an increase of the stereoscopic effect by showing surface details. The remaining photographs

et en 6, il s'agit aussi d'une vue stéréoscopique pour laquelle x, y et z seulement ont été utilisés (les données I ne sont pas utilisées). Les ombrages sont créés en dérivant les données de distance suivant l'axe des x. Ce traitement des données augmente l'effet stéréoscopique en révélant des détails de surface. Les autres photographies nous montrent différentes représentations du fichier x, y, z. En 2 nous avons des lignes de contour représentant des élévations de même valeur (similaire aux cartes topographiques). En 9 nous avons essentiellement la même chose pour un codage en couleur des données d'élévation. En 10 nous utilisons un logiciel de "rendu" afin d'obtenir une photographie "synthétique" des données tridimensionnelles (il y a trois sources de lumière suivant trois orientations différentes). En 4 nous montrons une représentation en fil de fer pour laquelle les lignes cachées ont été enlevées, et, finalement en 1 et 3 nous montrons deux différentes vues isométriques.

show various representations of the x, y, z data. In 2 we have contour lines of equal elevation (similar to topographical maps). In 9 we have essentially the same thing, using false colour coding. In 10 we use a solid modelling software to generate a "synthetic" photograph of the three-dimensional data (using three light sources under three different orientations). In 4 we have a wire mesh representation with hidden line removal and finally in 1 and 3 we have two isometric views.

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PRÉFACE / PREFACE

Introduction

Ce livre contient les illustrations reliées aux fichiers d'images tridimensionnelles prisent aux laboratoires du CNRC. La caméra tridimensionnelle utilisée est basée sur un système à balayage laser récemment mis au point à la Division de génie électrique. Les fichiers sont disponibles au lecteur sous la forme de données écrites sur rubans magnétiques ou sur disquettes. (Veuillez consulter la page couverture intérieure pour plus d'informations.) Les illustrations sont une source complémentaire d'information sur les détails de la caméra tridimensionnelle utilisée pour l'enregistrement des fichiers de données et les paramètres importants de chaque fichier.

Il y a deux photographies pour chaque fichiers. L'une est l'image tridimensionnelle codée en niveaux de gris, l'autre est la dérivée des mêmes données. Cette dernière fournie beaucoup de détails de surface très utile au scientifique qui étudie et traite ces données. Elle donne l'apparence similaire à une photographie d'une forme tridimensionnelle éclairée à incidence rasante. Le but de ce travail est de fournir au scientifique-informaticien une banque d'images tridimensionnelles pouvant être utilisées pour une variété d'activités de recherche, par exemple:

- Intégration de multiples vues du même objet pour former un modèle.
- Créer une bibliothèque de modèles d'objet pour éprouver des algorithmes de recherche et de description d'image.

Introduction

This book contains illustrations related to three-dimensional image data files which were taken at the NRCC laboratories. The three-dimensional camera used is based on a synchronized laser scanner recently developed at the Division of Electrical Engineering. The files are available to the reader in the form of data written on magnetic tapes or diskettes. (Please refer to the inside cover for more information.) The illustrations are a complementary source of information which gives details about the three-dimensional camera used to record the image data files and some useful parameters about each file.

There are two photographs shown per file. One is the three-dimensional grey level coded picture, the other one is the derivative picture of the same file. The latter one provides many surface details which are useful for the scientist who studies and processes them. Its appearance is similar to a photograph of the three-dimensional shape taken at an oblique illumination. The purpose of this work is to provide the computer scientist with a bank of three-dimensional images which can be used for a variety of research activities, for example:

- Integration of multiple views of the same object to form a model
- Creation of a library of object models to investigate searching algorithms and image description
- Development of interactive procedures to measure, manipulate, and edit three-dimensional information.

• Développer des procédures interactives de mesure, de manipulation et d'édition d'information tridimensionnelle.

Les champs d'intérêts sont:

- vision pour la robotique
- traitement d'image
- comprehension d'image
- graphique
- animation
- métrologie
- portrait tridimensionnel
- reconnaissance de visage humain (sécurité)
- anthropométrie
- applications médicales
- inspection
- modélisation
- guidage de véhicule
- fabrication de moulage
- CAO/FAO
- assemblage automatique
- automatisation
- reproduction d'objet
- applications pour les musées

Arrangement géométrique de la caméra tridimensionnelle

La figure 1 nous montre l'arrangement optique qui est utilisé pour effectuer les mesures tridimensionnelles sur les objets. Il s'agit d'un système à triangulation utilisant une projection laser. Les performances sont optimisées par l'utilisation d'une technique de synchronisation par laquelle la projection d'un faisceau laser et sa détection sont balayées à la même fréquence. On utilise un galvanomètre à miroir afin d'effectuer la synchronisation. Ceci est réalisé par l'utilisation d'un miroir dont les deux faces sont revêtues d'une couche

Fields of interest are:

- robot vision
- image processing
- image understanding
- graphics
- animation
- metrology
- three-dimensional portrait
- human face recognition (security)
- antropometry
- medical applications
- inspection
- modelization
- vehicule guidance
- mold fabrication
- CAD/CAM
- automatic assembly
- automation
- object reproduction
- museum applications

Geometry of the Three-dimensional Camera

Figure 1 shows the optical arrangement that is used to make three-dimensional measurements of objects. It is basically an active triangulation approach. Performances are optimized using a technique of synchronization by which the projection of a laser beam and its detection are scanned at the same frequency. It uses a galvanometer driven mirror to produce the synchronized projection and detection. This is obtained by a double-sided coated mirror. One side is used for the projection of a laser beam on the scene while the other side is used for the synchronized detection. The projection and detection axes define a reference plane from which the profiles of the objects in the field of view of the camera are measured. Each measurement provides x, y, z coordinates of the

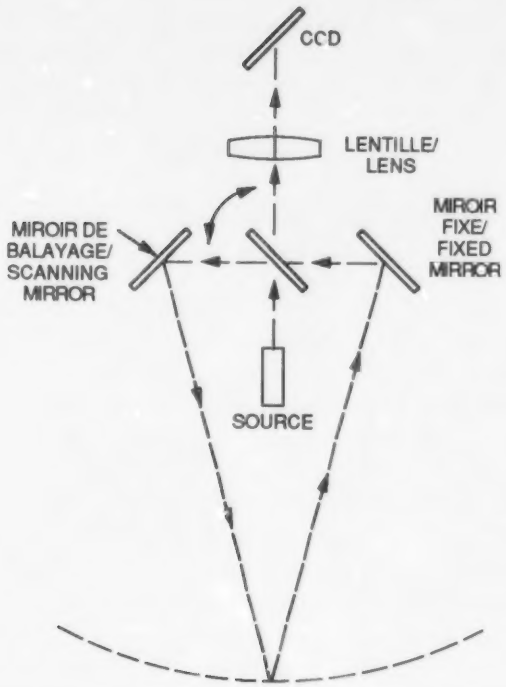


Figure 1 Système de mesure 3D utilisant la triangulation et l'autosynchronisation. / 3-D measurements using triangulation through synchronized scanners.

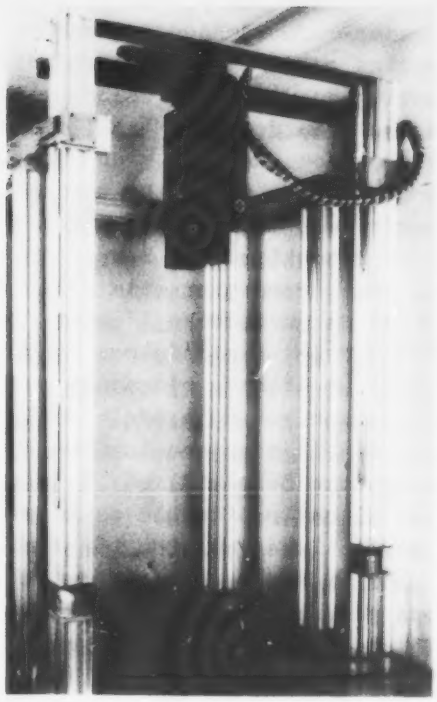


Figure 2 Photographie du prototype expérimental. / Photograph of the experimental prototype.

réflectrice. Un côté est utilisé pour la projection du laser sur la scène tandis que l'autre côté est utilisé pour assurer la synchronisation de la détection. Les axes de projection et de détection définissent une surface de référence à partir de laquelle le profil des objets dans le champs de vision est mesuré. Chaque mesure nous donne les coordonnées x, y, z de l'intersection du faisceau projeté avec la surface de l'objet ainsi que l'amplitude de la lumière diffusée (image d'intensité). Cette opération est réalisée grâce à l'utilisation d'un détecteur de position (ici une barrette CCD) et une lentille collectrice. La position du

projected beam on the surface of the object along with the amplitude of the scattered beam (intensity image). This is done using a position sensor (a CCD linear array) and a collecting lens. The position of the scattered beam on the CCD gives z (or range value) while the scanning mirror and the position of the camera (along the y axis) give x and y, respectively. The intensity is obtained using the amplitude of the CCD pulse, which is proportional to the reflectivity of the surface of the object. The CCD is tilted in order to compensate defocusing that happens along the z axis. Although incoherent light can be used for projection, the preferred source of light is usually a

faisceau diffusé sur la barrette CCD nous donne la coordonnée z (données d'élévation ou de distance) tandis que la position du miroir de balayage ainsi que la position de la caméra (le long de l'axe y) nous donnent respectivement les coordonnées x et y. La coordonnée d'intensité est obtenue par l'amplitude du signal détecté sur la barrette CCD, laquelle est proportionnelle à la réflectivité de surface de l'objet. La barrette CCD est inclinée par rapport à l'axe optique afin de compenser pour la défocalisation qui se produit le long de l'axe z. Bien qu'une lumière incohérente puisse être utilisée à la projection, il est préférable de se servir d'une source laser afin de bénéficier de la très grande profondeur de champs que nous procure la cohérence spatiale. Plus d'information concernant cette technique est disponible dans les publications listées en référence (1 à 5). Des informations complémentaires sont aussi disponible dans les références 6-11.

Le prototype experimental

La figure 2 nous montre le prototype expérimental qui est utilisé pour effectuer les mesures tridimensionnelles illustrées dans ce livre. Une fibre optique amène un faisceau laser de 10 mW (He-Ne émettant à 633 nm) à l'intérieur de la caméra (une boite noire en haut de la photographie). La ligne de balayage (la ligne blanche sur le masque et sur la table) définit l'axe x. La caméra est attachée à une unité de translation motorisée et sa direction de mouvement est perpendiculaire à l'axe du balayage. Ceci définit l'axe y. La mesure effectuée au niveau de la barrette CCD (ref. à la

laser because of the large depth of view that the spatial coherence provides. More information concerning the technique can be found in references 1 to 5. Complementary information is available in references 6 to 11.

The Experimental Prototype

Figure 2 shows the experimental prototype which was used to make all the measurements displayed in this book. An optical fiber is used to bring a 10 mW He-Ne laser beam (633 nm) into the camera head (a black box at the top of the photograph). The scanned line (white line on the mask and the table) defines the x axis. The camera head is attached to a motorized linear positioner and is translated perpendicular to the laser scan. This defines the y axis. The measurement made at the CCD (see Fig. 1) is proportional to the elevation of the object point under observation. It may also be called "range." The z axis is defined along that direction which is normal to the plane defined by the x and y axes.

The Acquisition of the Three-dimensional Data

Two scanning modes are used. The first one is sinusoidal, the second triangular. In both cases the acquisition of data is made in only one direction of the scan (from left to right facing the mask in Fig. 2). All the acquisitions (except those made on human faces) have been made using sine-wave scanning. Because the sampling is done at regular intervals (100 µs) there will be a large geometrical distortion of the raw data if they are

figure 1) est proportionnelle à l'élévation du point observé sur l'objet. Nous l'appelons aussi donnée de distance. L'axe z est ainsi définit le long de cette direction qui est normale au plan définit par les axes x et y.

L'acquisition des données tridimensionnelles

Deux modes de balayage sont utilisés. Le premier est sinusoïdal, le second triangulaire. Dans les deux cas l'acquisition des données est faite dans une seule direction du balayage (de gauche à droite en faisant face au masque de la figure 2). Toutes les acquisitions (à l'exception de celles prises sur des visages) ont été réalisées par l'utilisation d'un balayage sinusoïdal. Parce que l'échantillonnage est effectué à interval de temps régulier (100 μs) il y aura une distortion géométrique importante des données d'acquisition si on les affiches sur une grille régulière au fur et à mesure qu'elles entrent en mémoire (les données elle-mêmes n'ont pas de distortion). Ceci est illustré à la figure 3. La figure 3a nous montre les données d'élévation affichées en niveau de gris dans l'ordre de l'échantillonnage (sans interpolation). L'axe x est horizontal et Δy est régulier à 1 mm. La figure 3b nous montre les même données après interpolation ($\Delta x = \Delta y = 1$ mm). Ici un certain nombre d'observations sont faites:

- Il n'y a pas de distortion géometrique à l'affichage après l'interpolation (nous utilisons une interpolation linéaire).
- Lorsque les données d'acquisition sont affichées sans interpolation (sur une grille régulière), il y a une

displayed on a regular array as they enter the memory (the data themselves are distortion free). This is illustrated in Fig. 3. Figure 3a shows the range data displayed in grey levels as they are sampled (without interpolation). The x axis is horizontal and Δy is regular at 1 mm. Figure 3b shows the same data after interpolation ($\Delta x = \Delta y = 1$ mm). Here, a number of observations can be made:

- There is no geometrical distortion at the display after interpolation (linear interpolation was used).
- When the raw data images are displayed without interpolation (on a regular grid), a distortion is clearly visible on the wing on the left side (this is due to sinewave scanning).
- The black band on the right is pixels added to standardize the format of the file supplied on magnetic tape. All the raw data image files contain 300 pixels per line. The width of the black band varies from one image to another. The added pixels are assigned values of zero, i.e., (x, z) = (0, 0).
- Shadow effects are visible on one side only referring to the raw data image. Those areas are illuminated by the laser beam but are not seen at the observation. In this case an arbitrary value is assigned to the x coordinate (100 mm) in order to distinguish it from the pixels added to the black band. Thus, in the shadow area (x, z) = (100 mm, 0). Note that valid data (i.e., those for which there is enough light at the detection) always have non-zero values along the z axis.
- Figure 3b (which is the interpolated file) shows the other type of shadow effect which is related to areas seen by the observation but not illuminated by the laser source.

distortion nettement visible sur l'aile du côté gauche (ceci est causé par le balayage sinusoïdal).

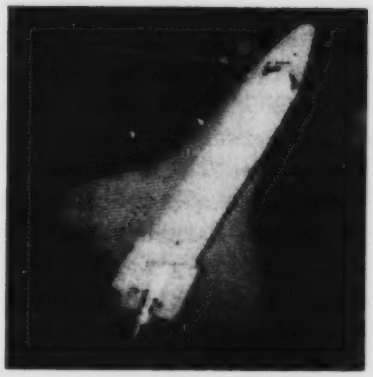
• La bande noire à droite représente des pixels que nous avons rajoutés afin de standardiser le format des fichiers que nous fournissons sur ruban magnétique. Tous les fichiers de données non-interpolées ou données brutes contiennent 300 pixels par ligne. La largeur de la bande noire varie d'une image à l'autre. Les valeurs des coordonnées rajoutées sont zéro, i.e., (x, z) = (0, 0).

• Des effets d'ombrage sont visibles sur un côté seulement de l'objet lorsqu'on se réfère à l'image des données d'acquisition. Ces surfaces sont illuminées par le laser mais elles ne sont pas vues du côté de l'observation. Dans ces cas nous donnons arbitrairement une valeur de 100 mm à la coordonnée x afin de différencier ces données de celles que nous rajoutons dans la bande noire. Ainsi dans les zones d'ombrage nous avons (x, z) = (100 mm, 0). Il est à noter que les données valides (i.e., celles pour lesquelles il y a suffisamment de lumière à la détection) ont toujours des valeurs non nulles suivant l'axe z.

• La figure 3b (qui provient des fichiers interpolés) nous montre l'autre type d'effet d'ombrage. Celui-ci est relié aux surfaces qui sont observables à la détection mais qui ne sont pas illuminées à la projection.

• Il y a deux bandes noires de chaque côté de la figure 3b. Encore ici, nous avons rajoutés un certain nombre de pixels aux fichiers interpolés afin de standardiser le nombre de pixels par ligne à 256. Dans ce cas-ci il n'y a pas de codage qui permette de différencier les effets d'ombrage et les bandes

(a)



(b)

Figure 3 (a) Les données à l'acquisition (z seulement) affichées sur une grille régulière telles qu'échantillonnées (grille de 300 × 256). Un balayage sinusoïdal était utilisé. (b) Les mêmes données après une interpolation linéaire (grille de 256 × 256). / (a) Raw data (z only) displayed on a regular grid as they are acquired (grid of 300 × 256). A sine wave scan has been used. (b) Same data after linear interpolation. (Grid of 256 × 256).

• There are two black bands on either side of Fig. 3b. Again, a number of pixels are added to some of the interpolated files in order to standardize

noires. En effet, dans les deux cas les valeurs de z sont arbitrairement mises à la valeur zéro. Notons que dans ce format nous avons une liste de coordonnées z seulement. L'information complémentaire (Δx, Δy) est écrite sous chacune des photographies correspondantes dans ce livre.

L'affichage des données de fichiers d'images tridimensionnelles

Comme nous montrent les illustrations de la page couverture, il y a plusieurs formes de présentation des données tridimensionnelles. Dans ce livre nous avons choisi de montrer les fichiers interpolés (x, y, z) pour lesquels z est codé en niveaux de gris, ainsi que sa dérivée suivant l'axe du balayage. Dans tout les cas l'image codée en niveaux de gris est à gauche de la page tandis que la dérivée est à droite. Pour la plupart des images la dérivée a été effectuée suivant l'axe x (qui est montré à l'horizontale pour la majorité d'entre elles). Les exceptions sont les images de visages pour lesquelles la dérivée est appliquée à un angle de 45° par rapport à l'axe x. Dans ce cas-ci l'axe du balayage (axe x) est affiché à la verticale.

Afin d'améliorer la présentation des images les zones d'ombrage sont interpolées dans le cas de la dérivée, mais ne sont pas interpolés pour les images de distance codées en niveaux de gris. De bons exemples sont montrés en haut des pages 82 et 83. Bien que la majorité des images aient leur axes x affichés à l'horizontale (à l'exception de tous les visages) il y en a quelques unes qui ont été tournées de 90° afin d'améliorer la présentation. Des

the number of pixels per line to 256. No coding is provided in this format to discriminate shadow effects and black bands. Indeed, z values are set at zero for both cases. Note that this format consists of a list of z values only. The complementary information (Δx, Δy) is printed under each corresponding photograph in this book.

The Display of the Three-dimensional Data Files

As can be seen from the illustrations on the front and back covers, there are many ways to display three-dimensional data. In this book the grey level coded images of the three-dimensional interpolated data are displayed, along with their derivatives along the x axis. For all cases the grey level coded images are on the left-hand side of the page while the derivatives are on the right-hand side. For most of the pictures the derivative has been taken along the x axis (which is horizontal for most of them). Exceptions are the human face pictures for which the derivative was applied at 45° of the x axis (note that the laser scan axis (x axis) is displayed vertical in this case).

For clarity of the display the shadow areas are interpolated in the derivative picture, which is not the case for the grey level coded picture. Good examples are the top photographs of pages 82 and 83. Although most pictures have their x axes displayed horizontally (with the exception of all the human faces) there are some pictures that have been rotated by 90° for presentation reasons only. Examples can

exemples sont aux pages 102 et 103 où les images #028, #302 et #042 ont l'axe x affiché à la verticale (direction du balayage laser).

Veuillez noter que pour le moment nous fournissons les fichiers contenant les coordonnées x, y, z seulement. Les données d'intensité ne sont pas disponibles pour cette édition.

Format des fichiers d'images 3D (Ruban magnétique 2400', 1600 BPI)

Comme décrit précédemment il y a deux formats de fichiers disponibles qui sont:

(1) les données interpolées (z), toujours des valeurs positives ou
(2) les données brutes (x, z) toujours des valeurs positive

Pour chacun des deux il y a deux codes:

(A) ASCII (5 octets), la valeur la moins significative = 10 μm
(B) BINAIRE (2 octets), la valeur la moins significative = 10 μm

Format 1 (F1A et F1B)

Ces données sont une liste de valeurs de z interpolées (à partir des données brutes) à intervalle régulier (Δx tel qu'indiqué sous les photographies). Pour tout les fichiers de ce format il y a 256 pixels (ou valeurs de z) par ligne. Chaque ligne est régulièrement espacée d'une valeur Δy (laquelle est aussi indiquée sous chaque photographie correspondante). Notons que pour les images interpolées Δx = Δy pour tous les fichiers. Chaque fichier est terminé par un code de fermeture (EOF).

be found on pages 102 and 103 where #028, #302, and #042 have their x axes vertical (laser scan direction).

Note that only x, y, z data are supplied at this time. Intensity data (I) are not available for this edition.

Three-dimensional Data Files Format (Tape 2400', 1600 BPI)

As explained before there are two formats of files for the three-dimensional data.

(1) interpolated data (z), always positive values or
(2) raw data (x, z), always positive values

For each one there are two codes available;

(A) ASCII (5 bytes), the least significant value = 10 μm
(B) BINARY (2 bytes), the least significant value = 10 μm

Format 1 (F1A and F1B)

Those data consist of a sequence of z values which are interpolated (from the raw data file) at regular intervals (Δx under the photographs). For all the files in this format there are 256 pixels (or z values) in a line. The successive lines in the files are uniformly spaced along the y axis by an amount equal to Δy (which is also specified under the corresponding photographs). Note that for interpolated images Δx = Δy for all the files. Each file is terminated by an end-of-file code (EOF).

Format 2 (F2A et F2B)

Les données brutes sont fournies sous la forme d'une séquence de couples (x, z) qui sont échantillonnés à intervalle de temps régulier par la caméra tridimensionnelle. Ces fichiers ne sont pas illustrés dans le livre. Pour tous les fichiers de ce format il y a 300 pixels (ou couples (x, z)) par ligne. Les lignes se succèdent à intervalle régulier de Δy (indiqué sous chaque photographie correspondante). Encore ici chaque fichier est terminé par un code de fermeture (EOF).

Notes additionnelles

Toutes les données disponibles sur rubans ou sur disquettes, dans les deux formats, sont calibrées.

Il y a une ligne par enregistrement et une image par fichier. Toutes les images (sauf celles des visages) ont 256 lignes.

Quant à elles, les images de visages ont 150 lignes seulement (notons qu'elles sont affichées à la verticale dans le livre).

Format des fichiers d'images tridimensionnelles (Disquettes 5¼", double densité, double côtés)

Il n'y a que les données interpolées qui sont disponibles sur disquettes. Nous utilisons quatre caractères ASCII plus un espace par pixel. Le caractère le moins significatif est égal à 25 µm. Il y a 32 pixels par

Format 2 (F2A and F2B)

The raw data consist of a sequence of (x, z) values which are sampled at regular intervals of time by the three-dimensional laser scanner. Those files are not illustrated in the book. For all the files in this format there are 300 pixels (or couples (x, z) in a line). The successive lines in the file are uniformly spaced along the y axis by an amount equal to Δy (which is printed under each photograph in the book). Again in this format, each file is terminated by an end-of-file code (EOF).

Additional Notes

All data supplied on tapes or diskettes in any format are calibrated.

There is one line per record and one image per file. All images (with the exception of human faces) have 256 lines.

The human face images have 150 lines per image (note they are displayed vertically in the book).

Three-dimensional Data Files Format (Diskette 5¼", Double Sided, Double Density)

Only interpolated data are available on diskettes. Four ASCII characters plus one blank space per pixel are used. The least significant character is equal to 25 µm. There are 32 pixels per record and 8 records per line. For all images but the ones of human faces there are 256 lines per image. The

enregistrement et 8 enregistrements par ligne. Pour toutes les images à l'exception des visages il y a 256 lignes par image. Les visages en compte 150 seulement (notons que les lignes sont affichées à la verticale dans le livre pour ce cas-ci). Finalement, il y a une image par disquette.

Remerciements

Les auteurs tiennent à remercier tous les collaborateurs de la Section photonique et capteurs pour leur support dans ce projet. Nous remercions tout spécialement le personnel du Bureau des publications de la Division de génie électrique pour leurs nombreux conseils lors de la préparation et l'édition de ce livre, et aussi Leslie Cameron de la Section de dessin et de photographie qui a patiemment coupé et collé les 428 illustrations des images 3D. Elle est aussi responsable de la conception graphique de la page couverture. Grand merci à Pierre Gariépy qui s'est occupé de toutes les questions relatives au format et à la reproduction des données sur ruban magnétiques et sur disquettes. Son expertise dans le domaine des ordinateurs est toujours très appréciée. Finalement, nous tenons à remercier tout les volontaires qui ont si gentillement accepté de voir leur physionomie transferrée à une mémoire d'ordinateur.

Références

1. Rioux, M. Laser range finder based on synchronized scanners. Appl. Opt. 23(21): 3877-3844; 1984.

2. Blais, F., et Rioux, M. Real-time numerical peak detector. Signal Process. 11: 145-155; 1986.

human face images have 150 lines per image (note that lines are displayed vertically in the book for these cases). Finally, there is one image per diskette.

Acknowledgements

The authors wish to thank all their collaborators in the Photonics and Sensors Section for their support in this project. We are especially grateful to the staff of the Editorial Office of the Division of Electrical Engineering for providing their expertise in the preparation and editing of this book and also to Leslie Cameron of the Drafting and Photography Section who patiently cut and pasted the 428 illustrations of the 3-D images. She is also responsible for the cover design. Many thanks to Pierre Gariépy who took care of the bits and bytes of the formatting and replication of the data files. His expertise in computers is always appreciated. Finally, we wish to express our thanks to those people who volunteered to have the topography of their faces transferred to a computer memory.

References

1. Rioux, M. Laser range finder based on synchronized scanners. Appl. Opt. 23(21): 3877-3844; 1984.

2. Blais, F., and Rioux, M. Real-time numerical peak detector. Signal Process. 11: 145-155; 1986.

3. Rioux, M., Bechthold, G., Taylor, D., and Duggan, M. Design of robotic applications. J. Opt. Soc. a large depth of view 3-D camera for robot vision. Opt. Eng. 26(12): 1245-1250; 1987.

3. Rioux, M., Bechthold, G., Taylor, D., et Duggan, M. Design of a large depth of view 3-D camera for robot vision. Opt. Eng. 26(12): 1245-1250; 1987.

4. Livingstone, F.R., et Rioux, M. Development of a large field of view 3-D vision system. SPIE Proc. 665: 188-194; June 1986.

5. Bumbaca, F., Blais, F., et Rioux, M. Real-time correction of 3-D nonlinearities for a laser range finder. Opt. Eng. 25(4): 561-565; 1986.

6. Boulanger, P., Evans, K.B., Rioux, M., et Ruhlmann, L. Interface between a 3-D laser scanner and a CAD/CAM system. Proceedings of the 5th Canadian CAD/CAM & Robotics Conference and Exposition, Toronto (Ont.), juin 1986. pp. 731-737.

7. Rioux, M., et Blais, F. Compact three-dimensional camera for robotic applications. J. Opt. Soc. Am. A3(9): 1518-1521; 1986.

8. Blais, F., et Rioux, M. BIRIS: a simple 3D sensor. SPIE Proc. 728: 235-242; 1986.

9. Blais, F., et Rioux, M. Real-time data acquisition algorithms and implementation for 3-D vision. SPIE Proc. 829: 72-79; 1987.

10. Lu, S.W., Wong, A.K.C., et Rioux, M. Recognition of 3-D objects in range image by attributed hypergraph monomorphism and synthesis. Proc. IFAC Conf. 1985. p. 389.

11. Rioux, M., Boulanger, P., et Kasvand, T. Segmentation of range images using sine wave coding and Fourier transformation. Appl. Opt. 26(2): 287-293; 1987.

4. Livingstone, F.R., and Rioux, M. Development of a large field of view 3-D vision system. SPIE Proc. 665: 188-194; June 1986.

5. Bumbaca, F., Blais, F., and Rioux, M. Real-time correction of 3-D nonlinearities for a laser range finder. Opt. Eng. 25(4): 561-565; 1986.

6. Boulanger, P., Evans, K.B., Rioux, M., and Ruhlmann, L. Interface between a 3-D laser scanner and a CAD/CAM system. Proceedings of the 5th Canadian CAD/CAM & Robotics Conference and Exposition, Toronto (Ont.), June 1986. pp. 731-737.

7. Rioux, M., and Blais, F. Compact three-dimensional camera for Am. A3(9): 1518-1521; 1986.

8. Blais, F., and Rioux, M. BIRIS: a simple 3D sensor. SPIE Proc. 728: 235-242; 1986.

9. Blais, F., and Rioux, M. Real-time data acquisition algorithms and implementation for 3-D vision. SPIE Proc. 829: 72-79; 1987.

10. Lu, S.W., Wong, A.K.C., and Rioux, M. Recognition of 3-D objects in range image by attributed hypergraph monomorphism and synthesis. Proc. IFAC Conf. 1985. p. 389.

11. Rioux, M., Boulanger, P., et Kasvand, T. Segmentation of range images using sine wave coding and Fourier transformation. Appl. Opt. 26(2): 287-293; 1987.

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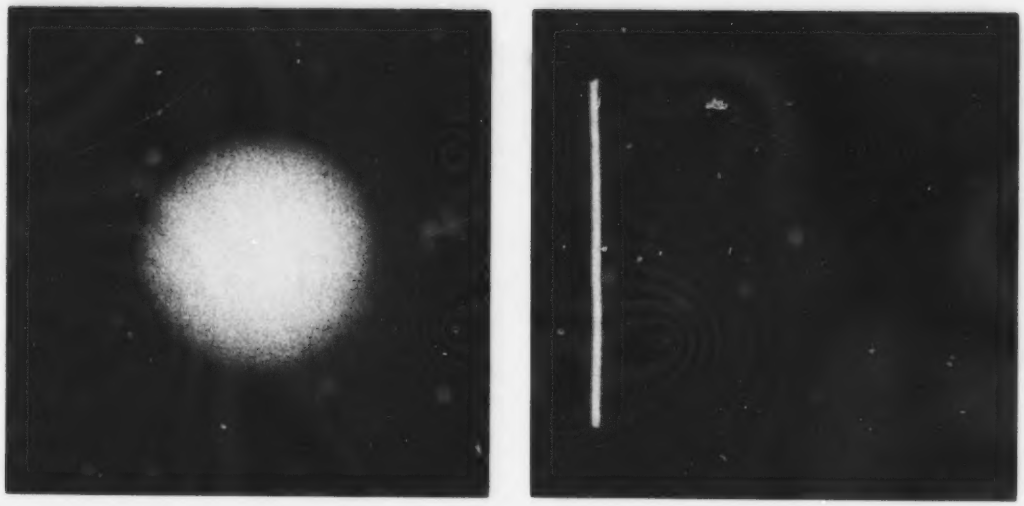

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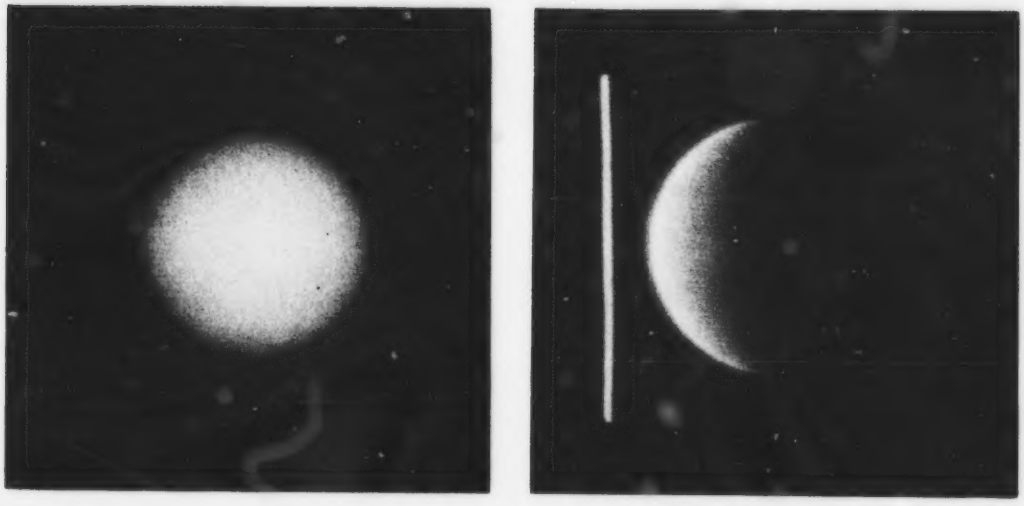

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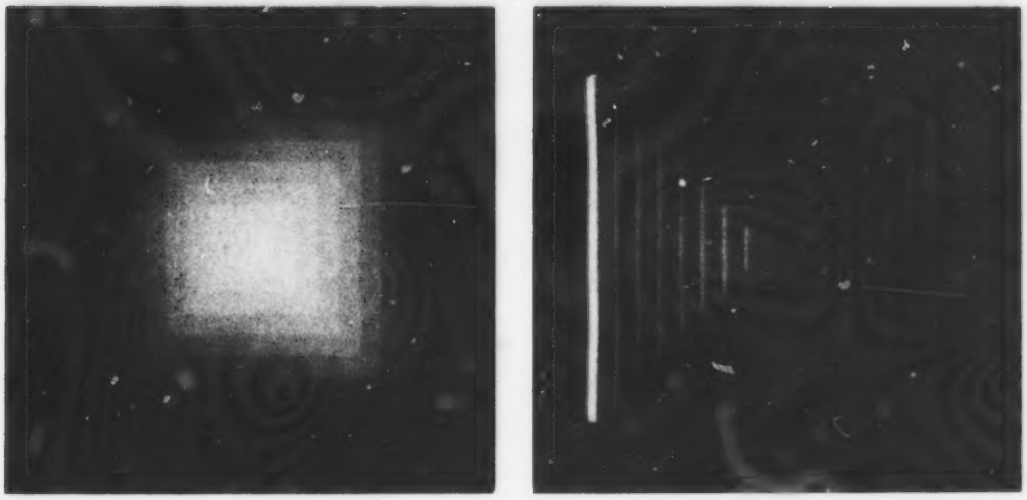

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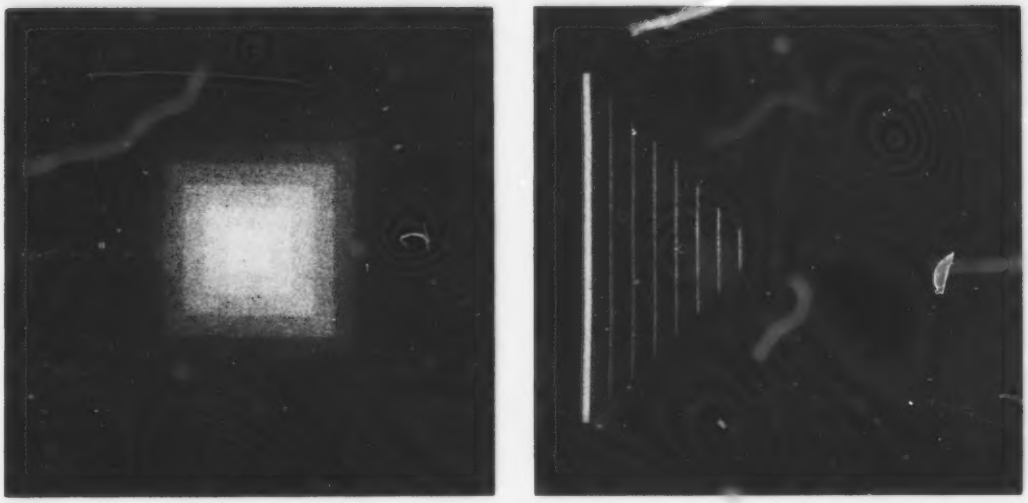

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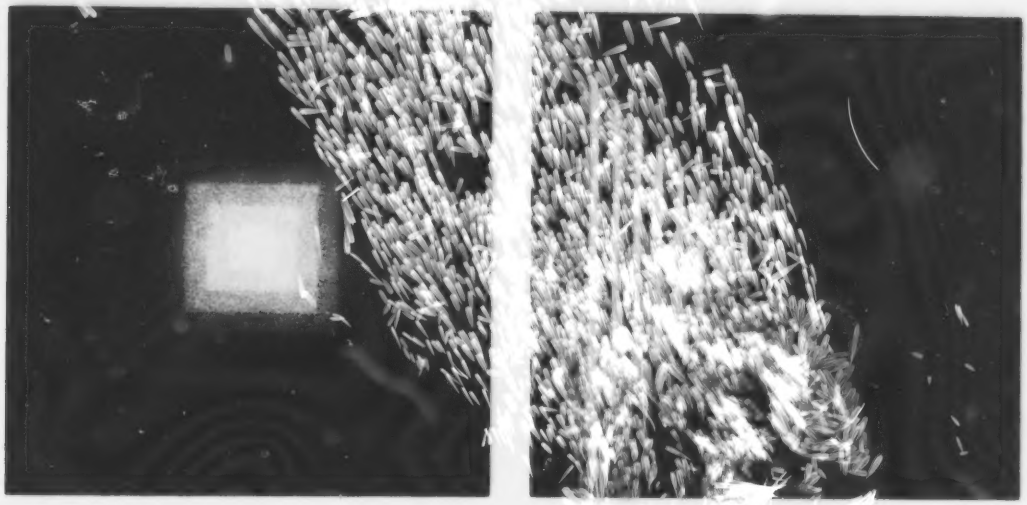

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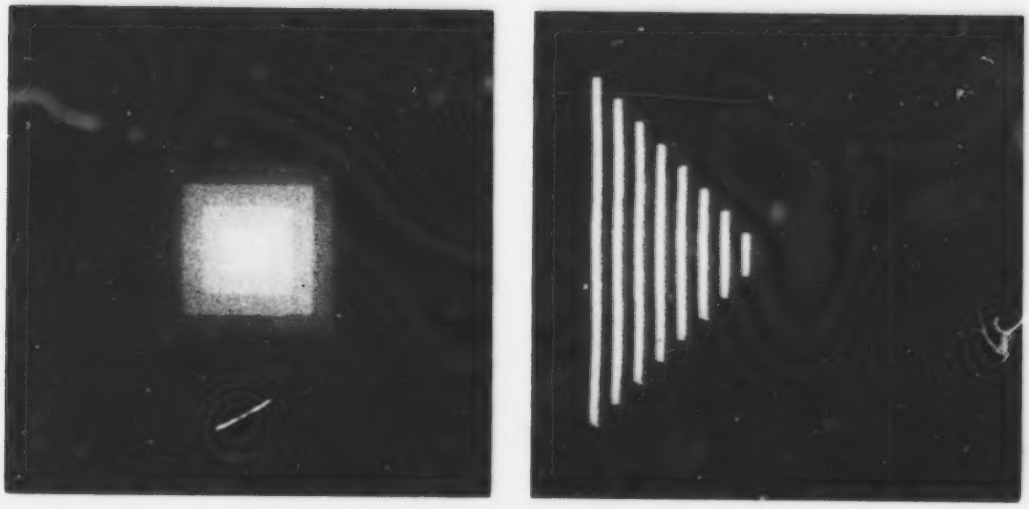

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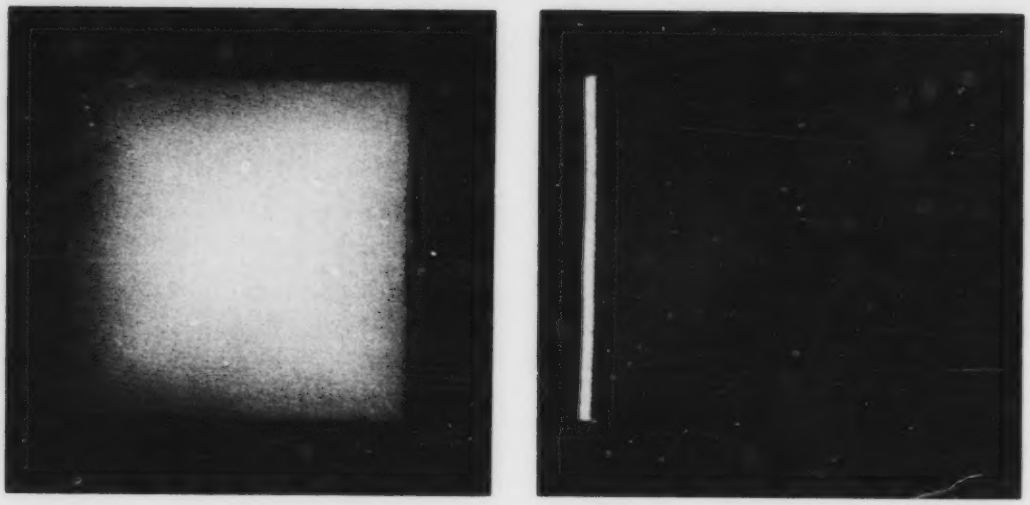

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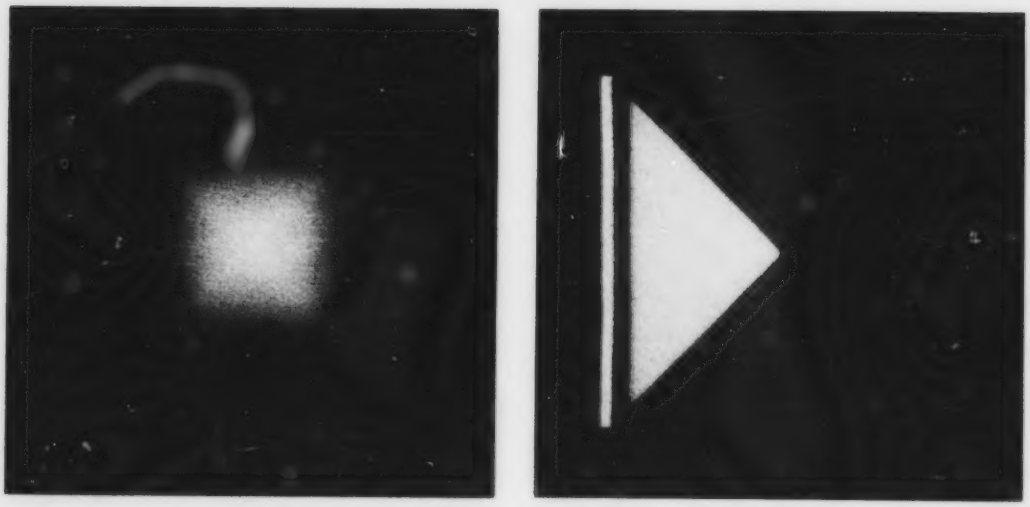

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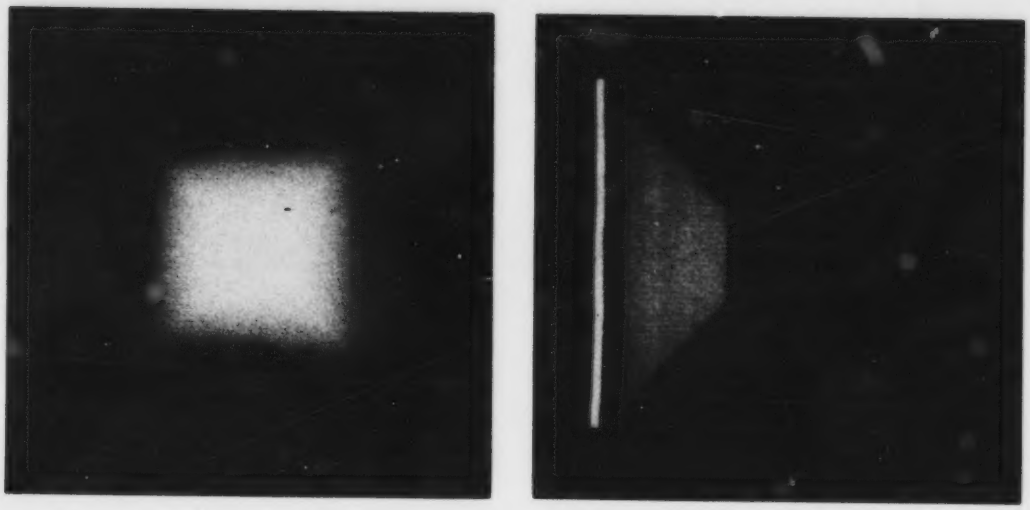

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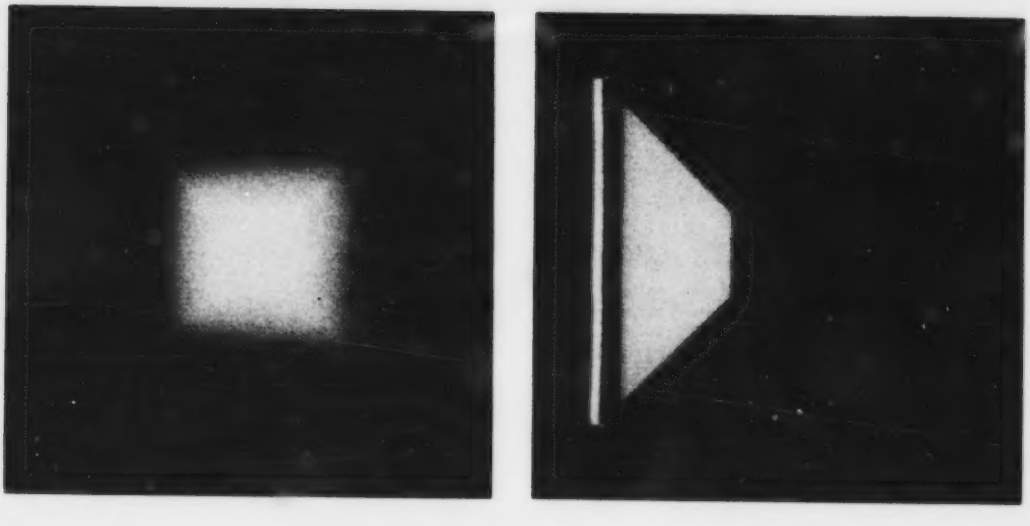

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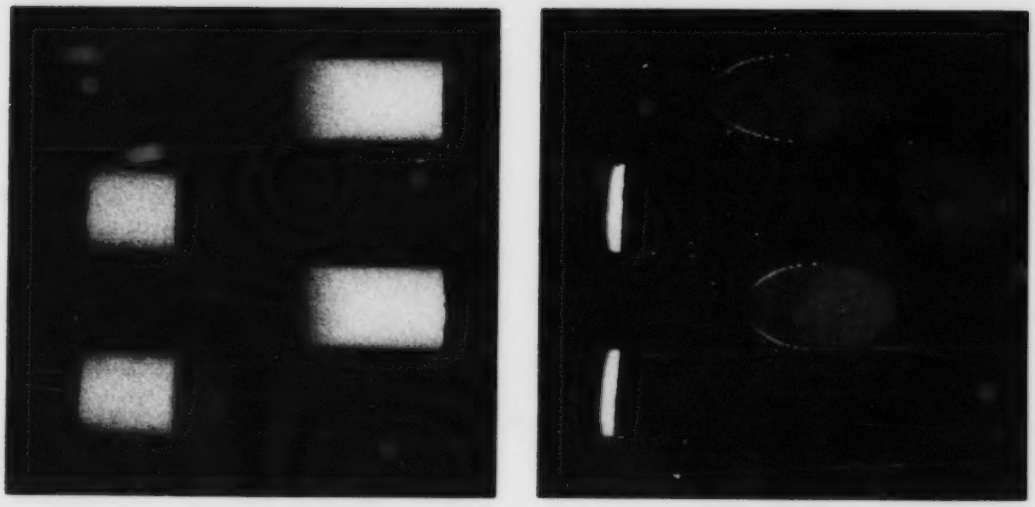

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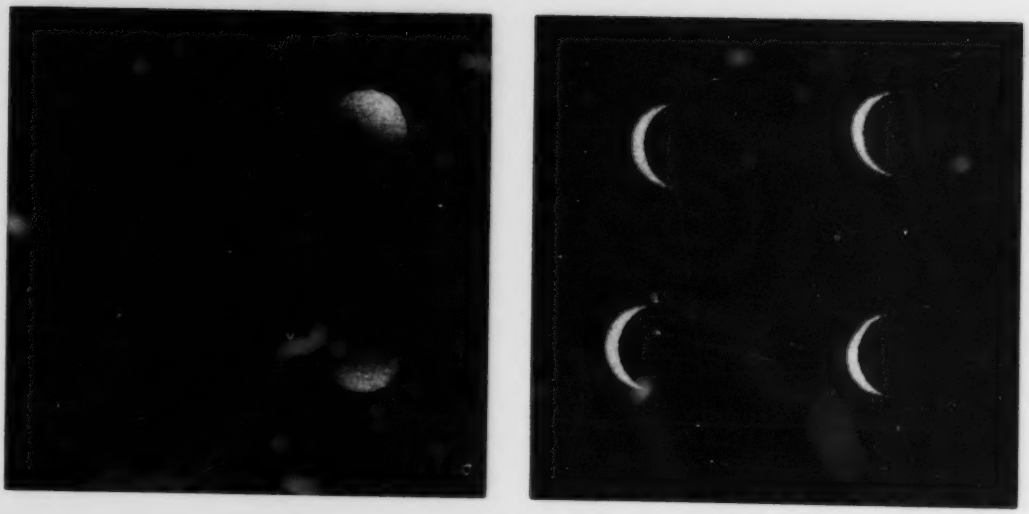

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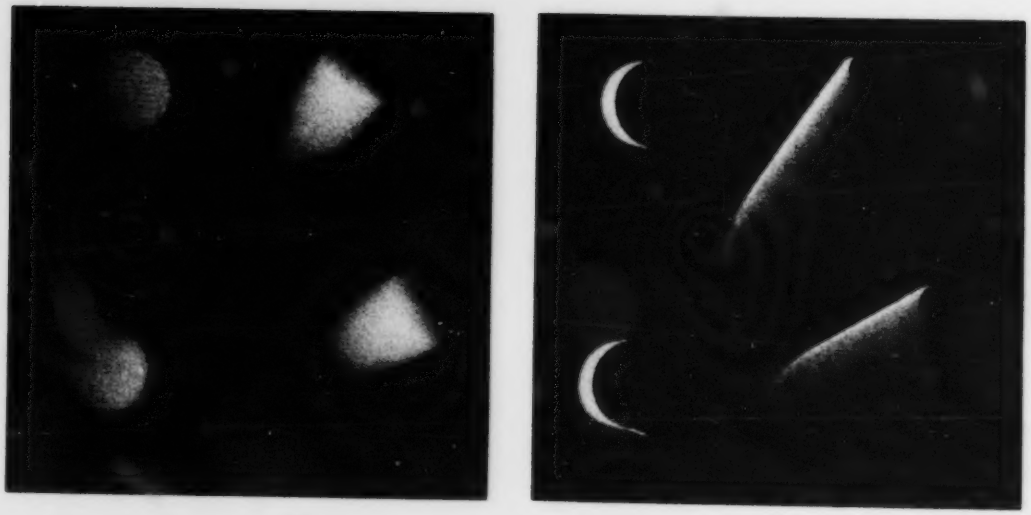

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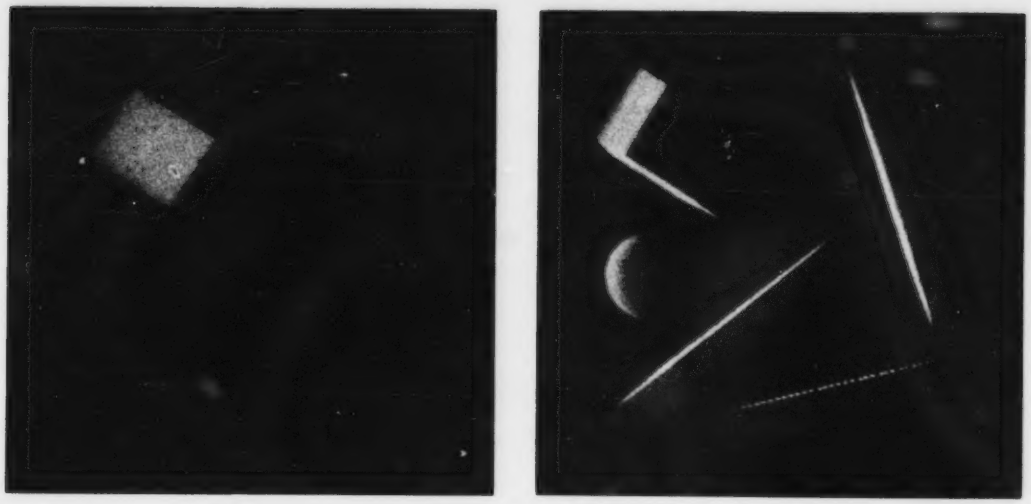

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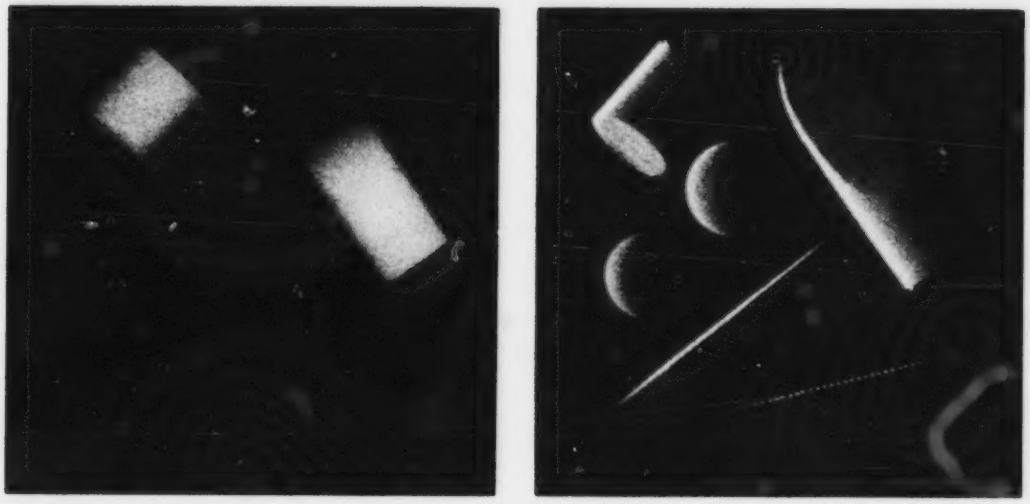

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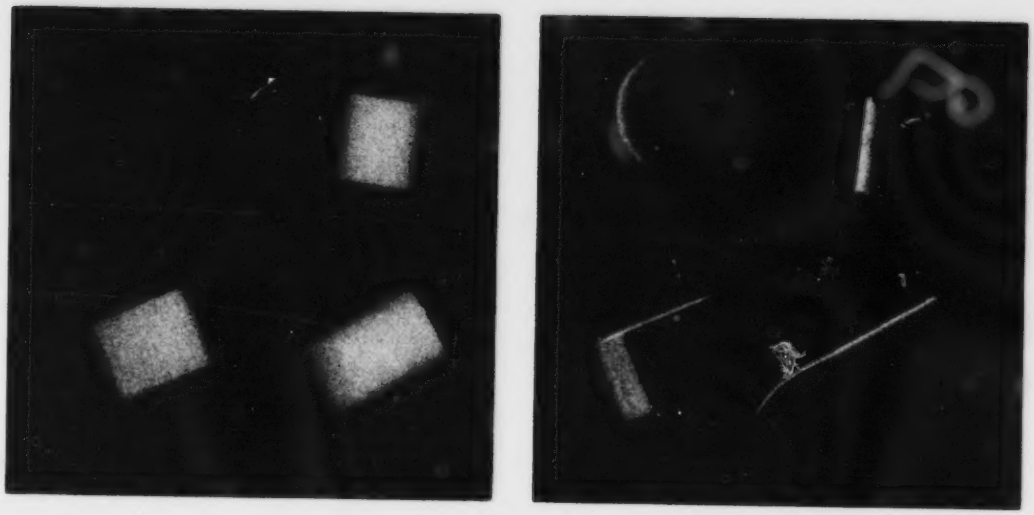

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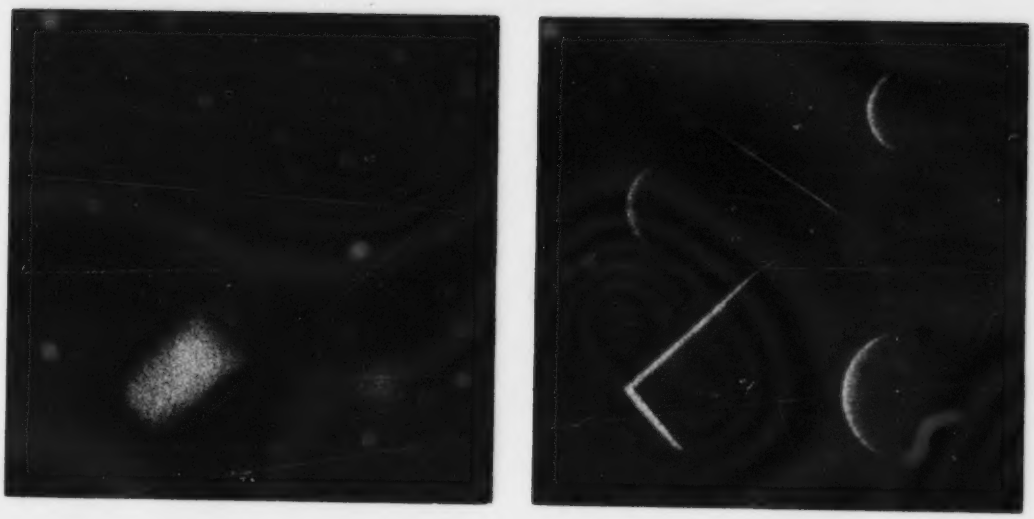

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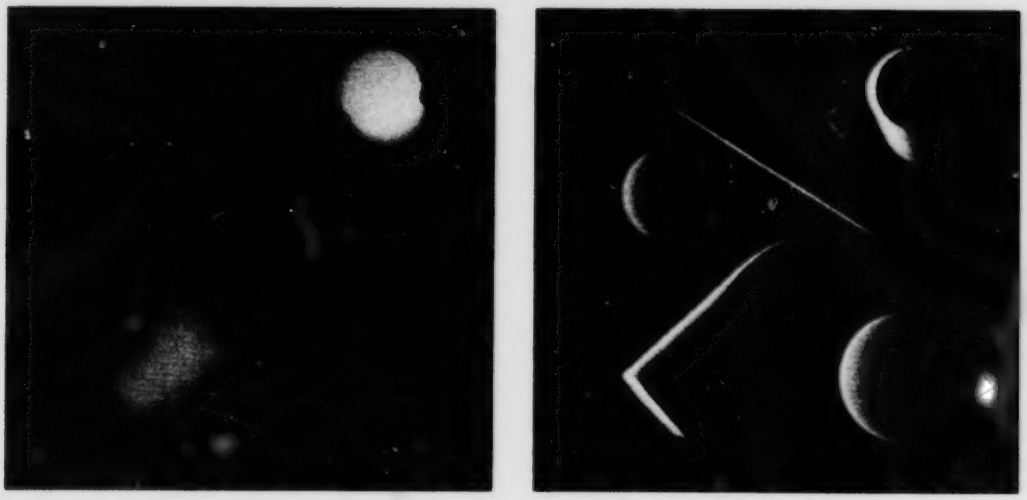

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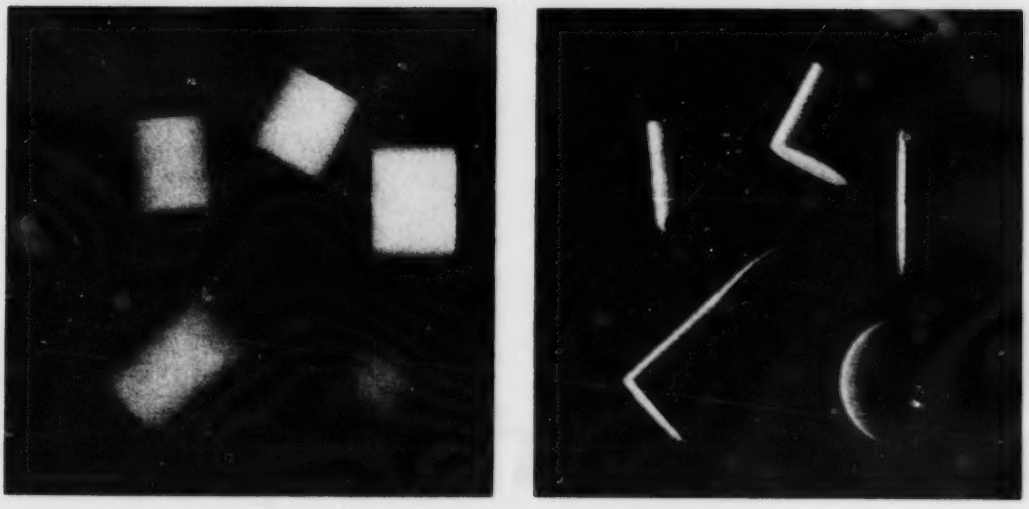

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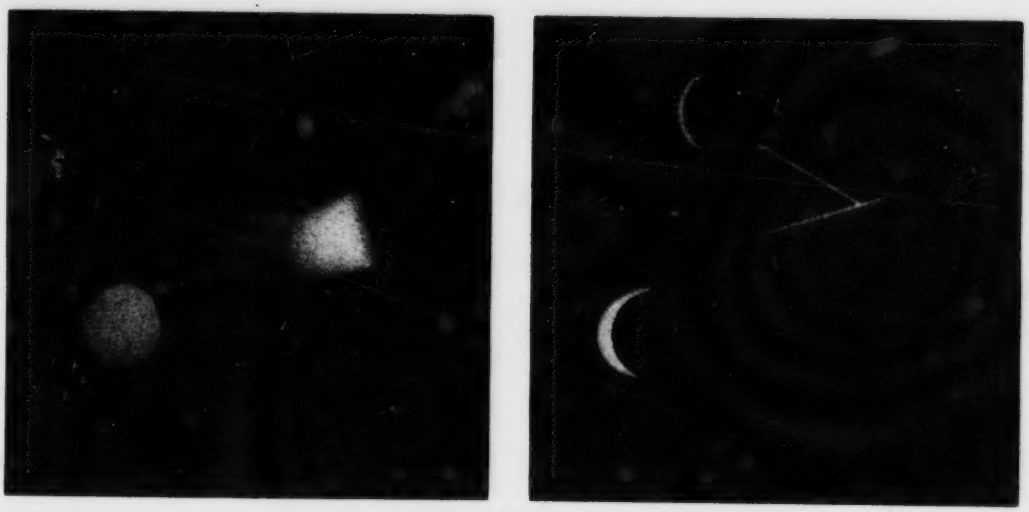

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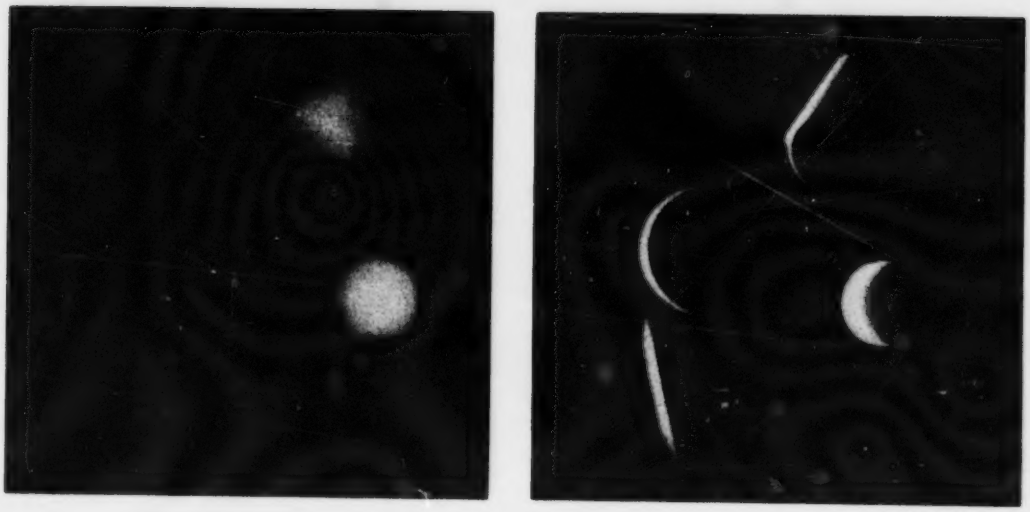

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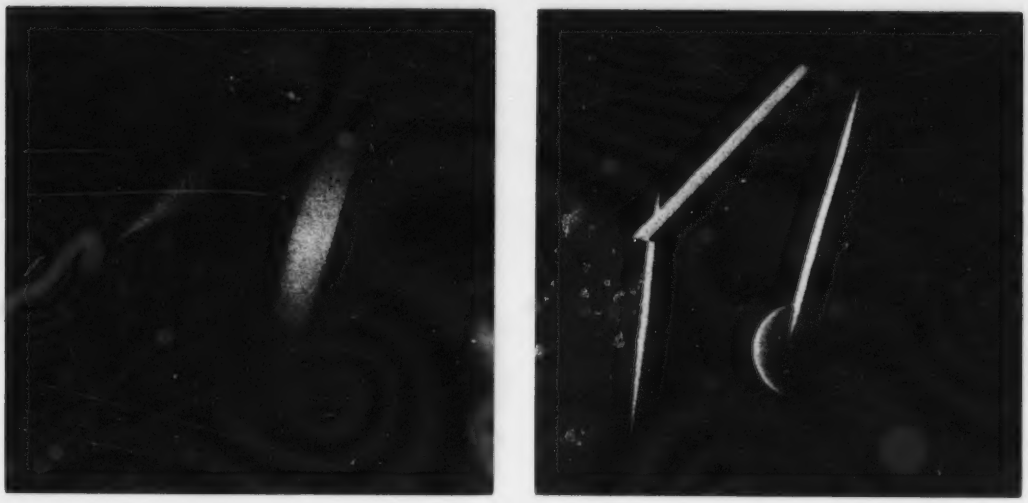

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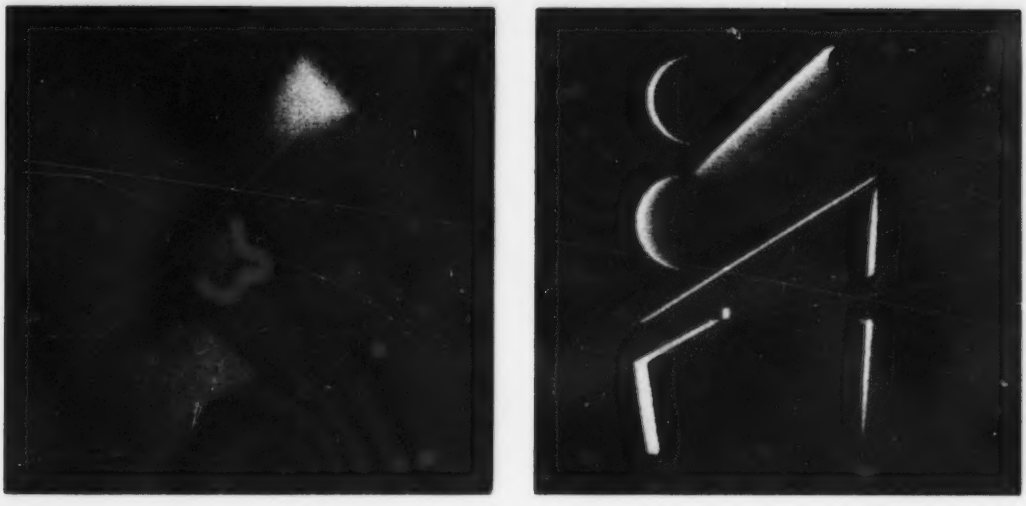

CAT # 107, BLOC 14

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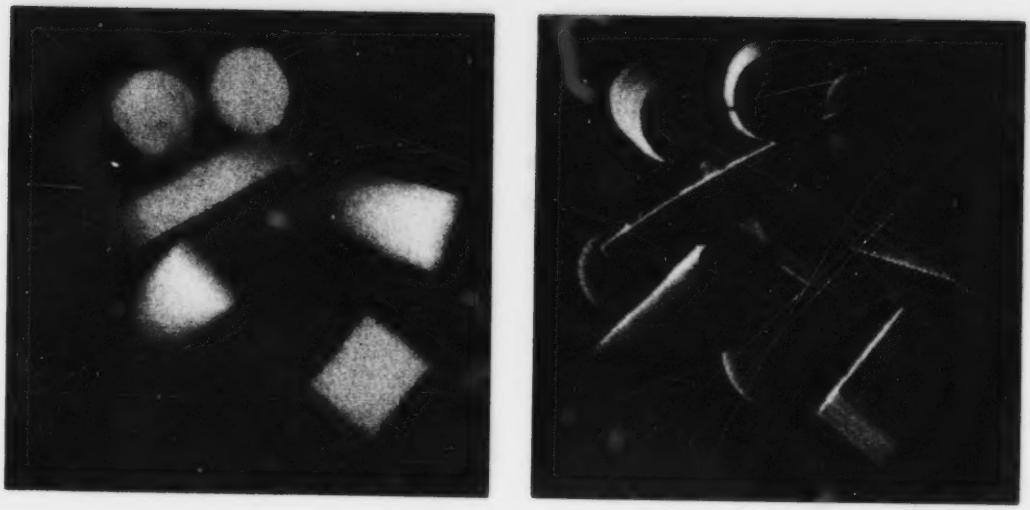
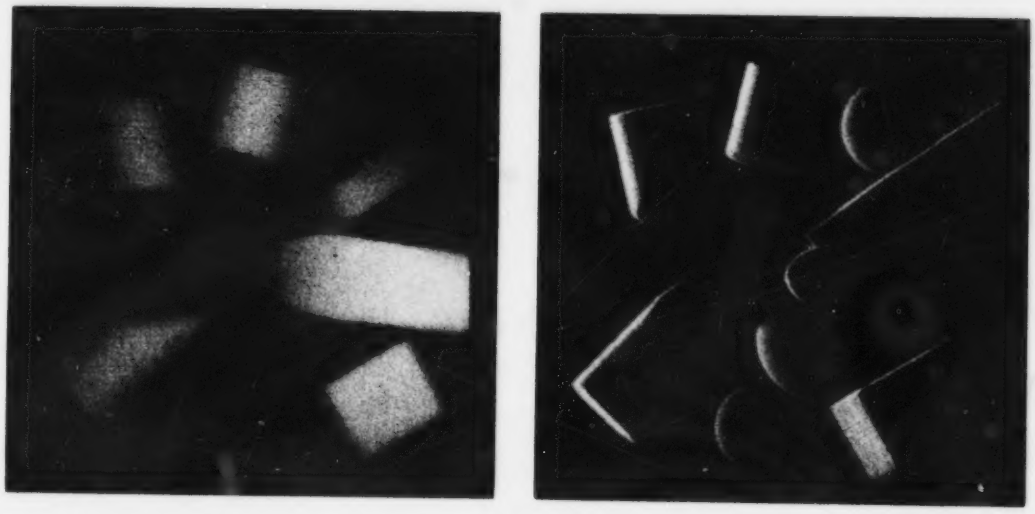


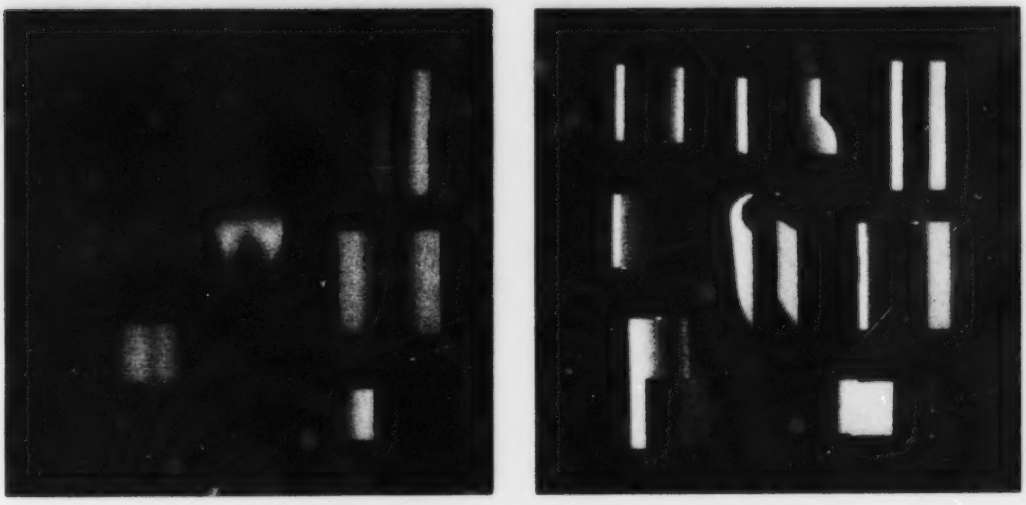
CAT # 106, BLOC 15

$\Delta x = \Delta y = 0.5$ mm



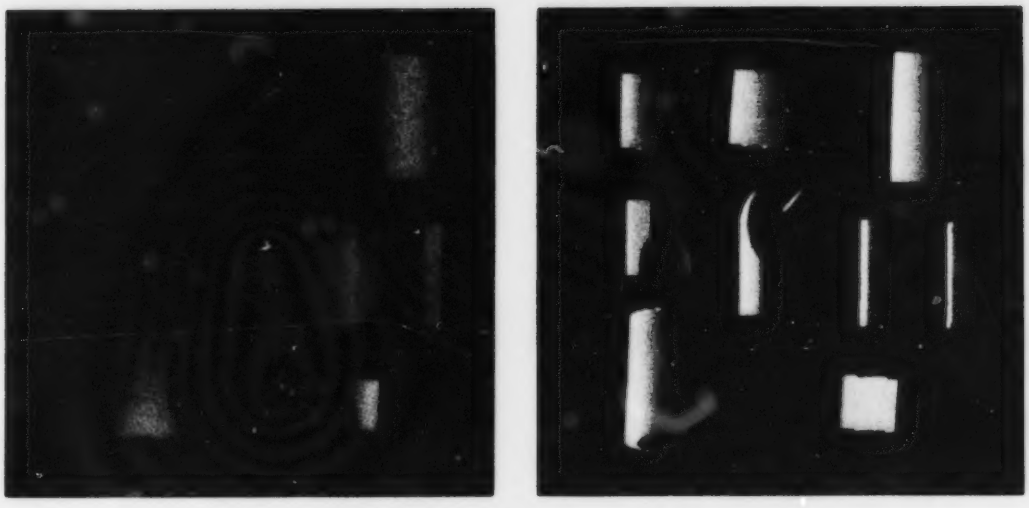
CAT # 105, BLOC 16

$\Delta x = \Delta y = 0.5$ mm



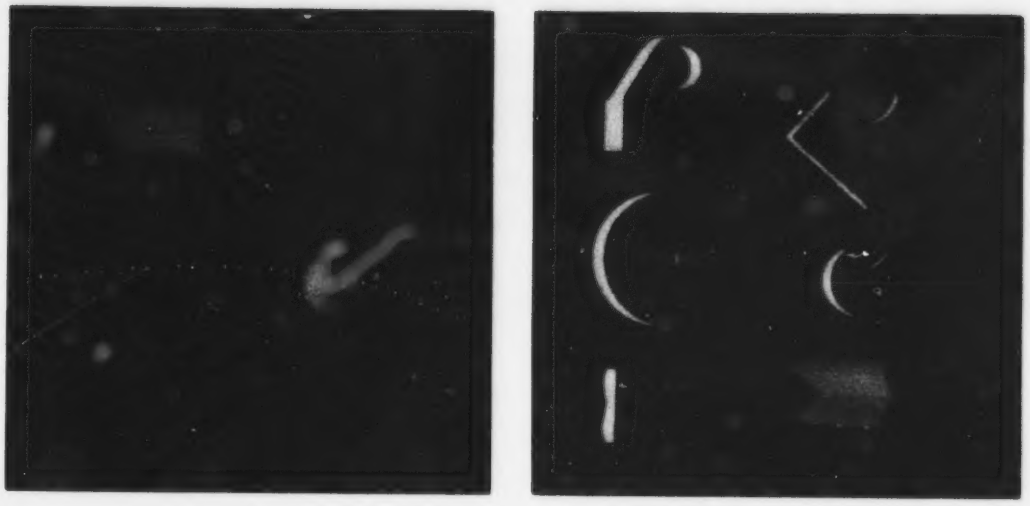
CAT # 081, BLOC 17

$\Delta x = \Delta y = 0.8$ mm



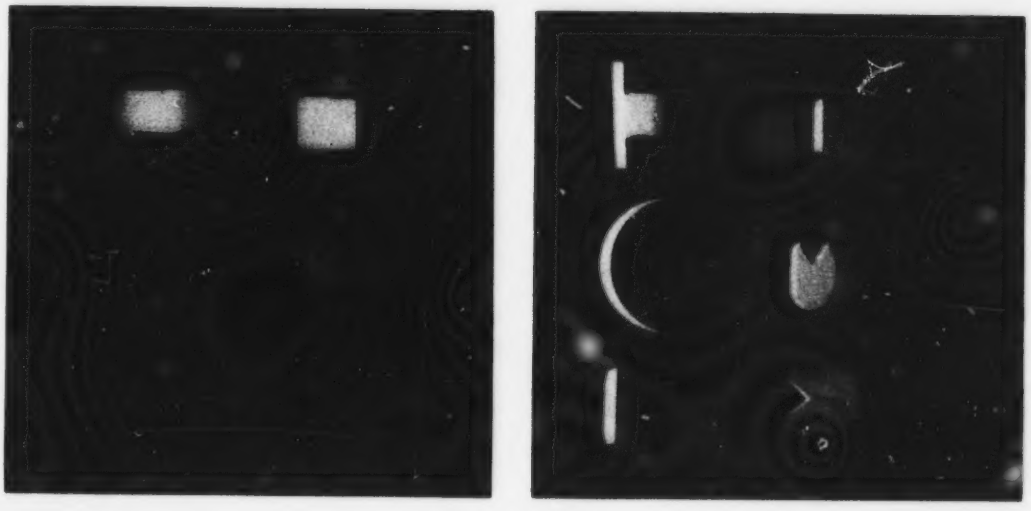
CAT # 082, BLOC 18

$\Delta x = \Delta y = 0.8$ mm



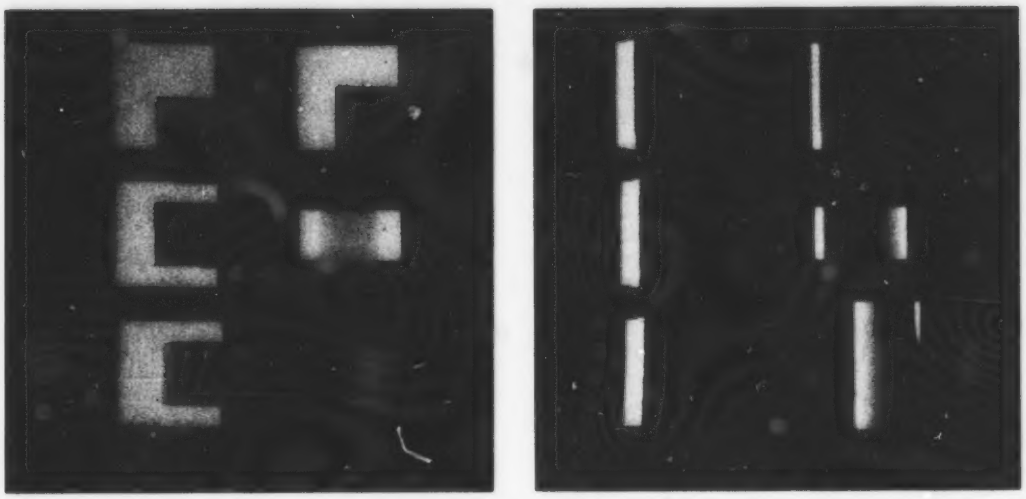
CAT # 084, BLOC 19

$\Delta x = \Delta y = 0.8$ mm



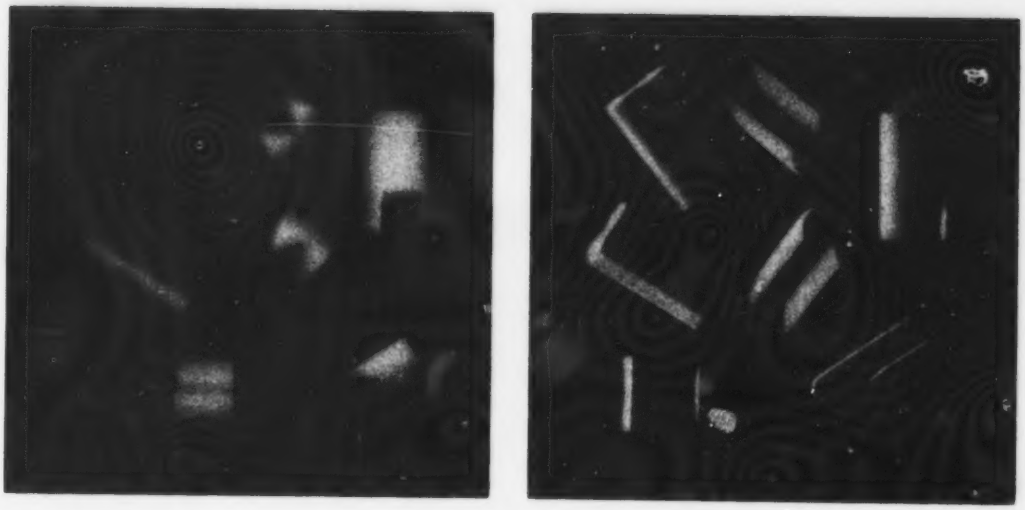
CAT # 085, BLOC 20

$\Delta x = \Delta y = 0.8$ mm



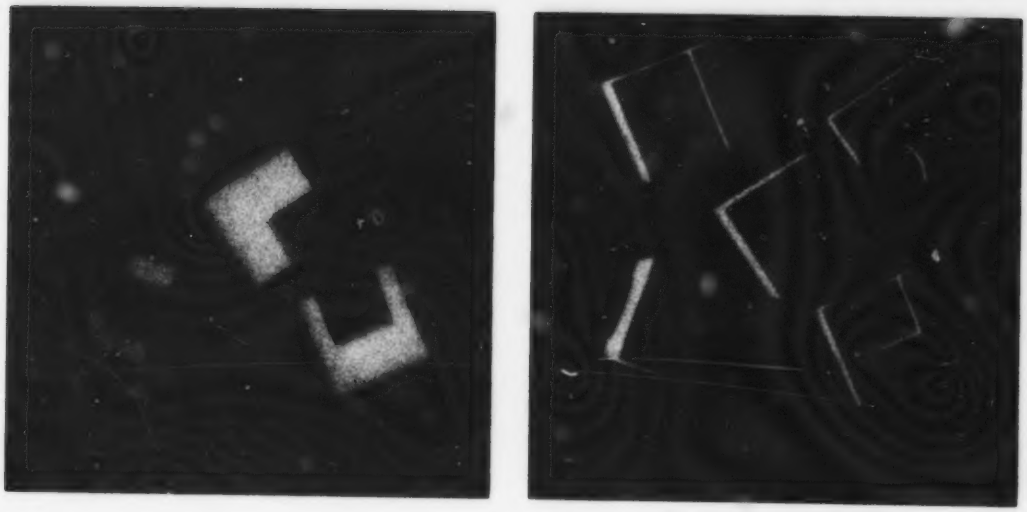
CAT # 083, BLOC 21

$\Delta x = \Delta y = 0.8$ mm



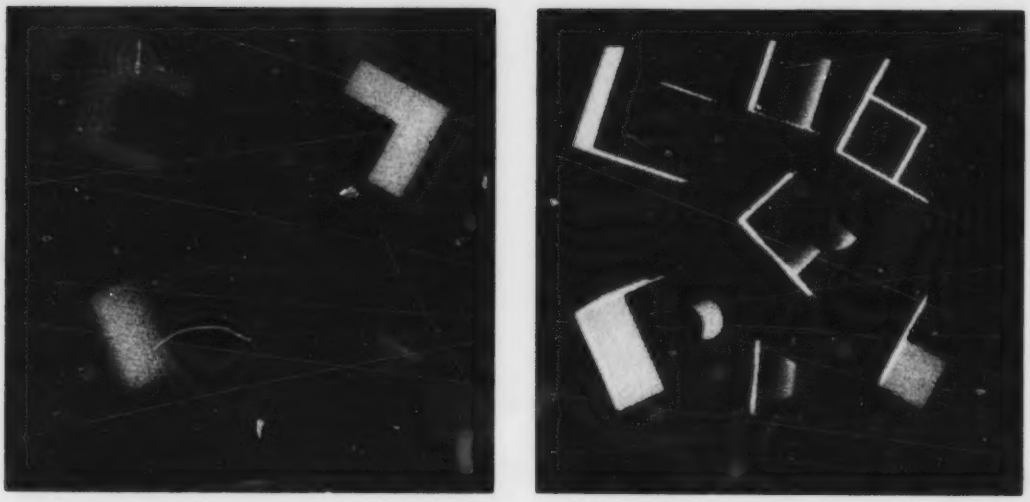
CAT # 086, BLOC 22

$\Delta x = \Delta y = 0.8$ mm



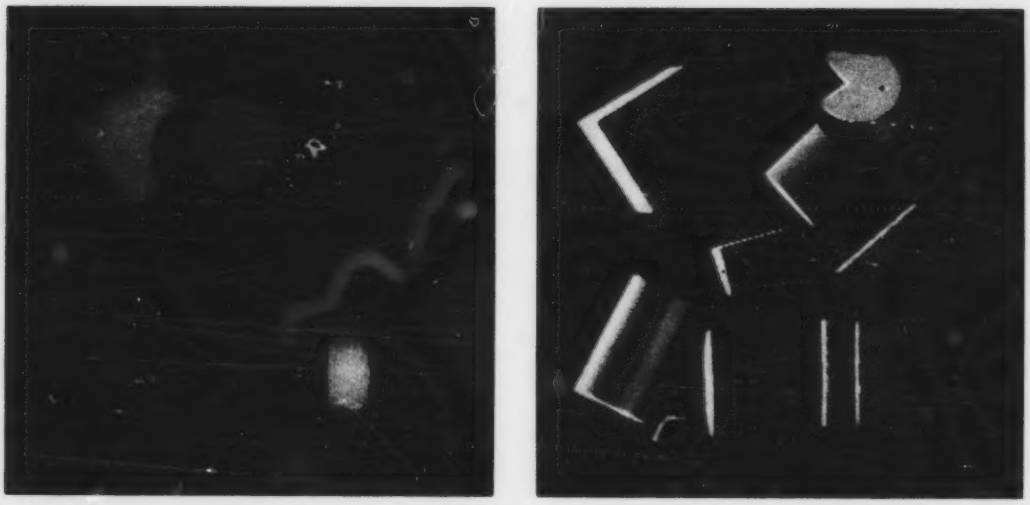
CAT # 087, BLOC 23

$\Delta x = \Delta y = 0.8$ mm



CAT # 088, BLOC 24

$\Delta x = \Delta y = 0.8$ mm

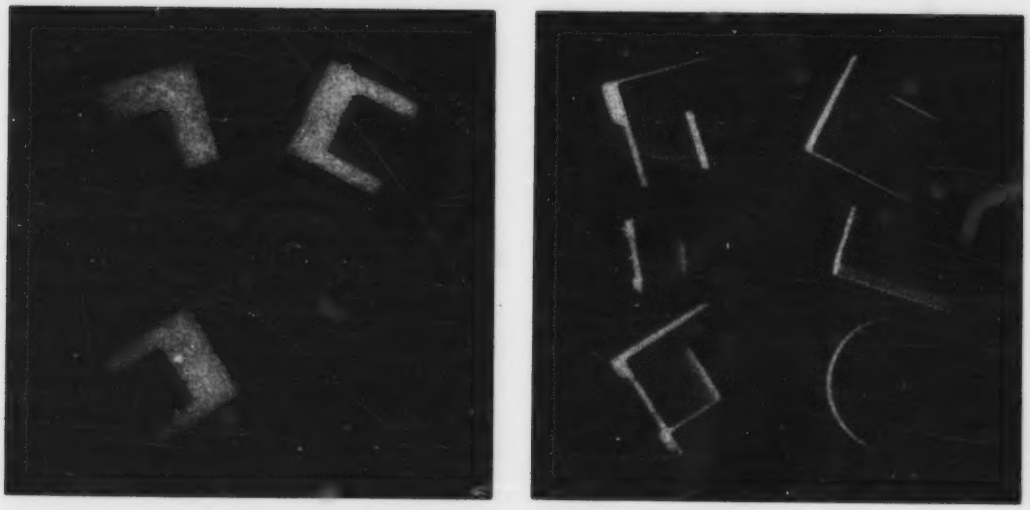


CAT # 089, BLOC 25

$\Delta x = \Delta y = 0.8$ mm

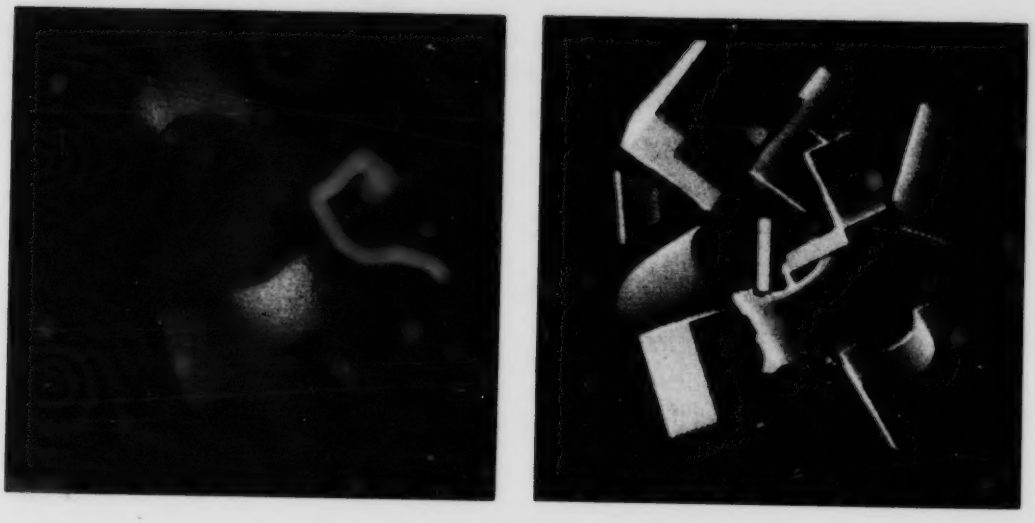
CAT # 090, BLOC 26

$\Delta x = \Delta y = 0.8$ mm



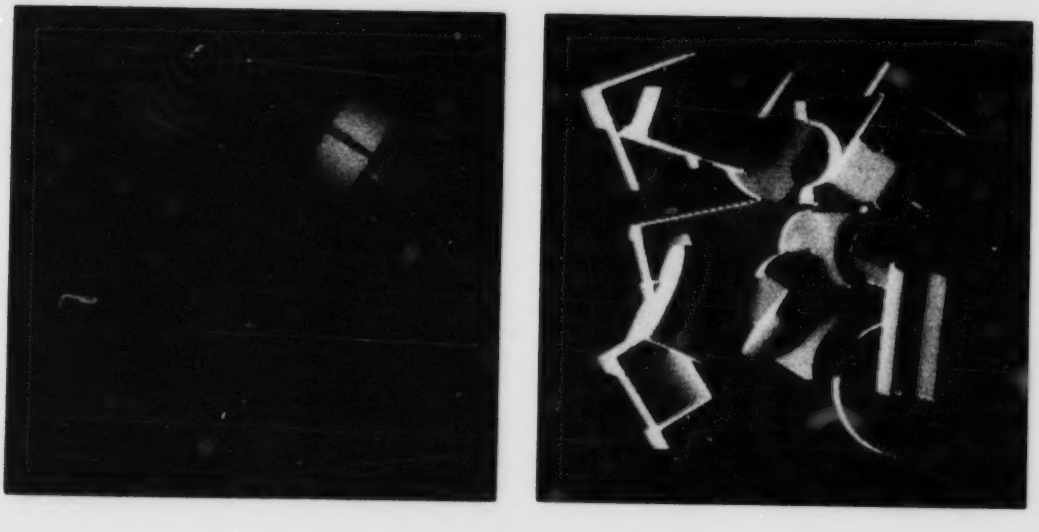
CAT # 091, BLOC 27

$\Delta x = \Delta y = 0.8$ mm



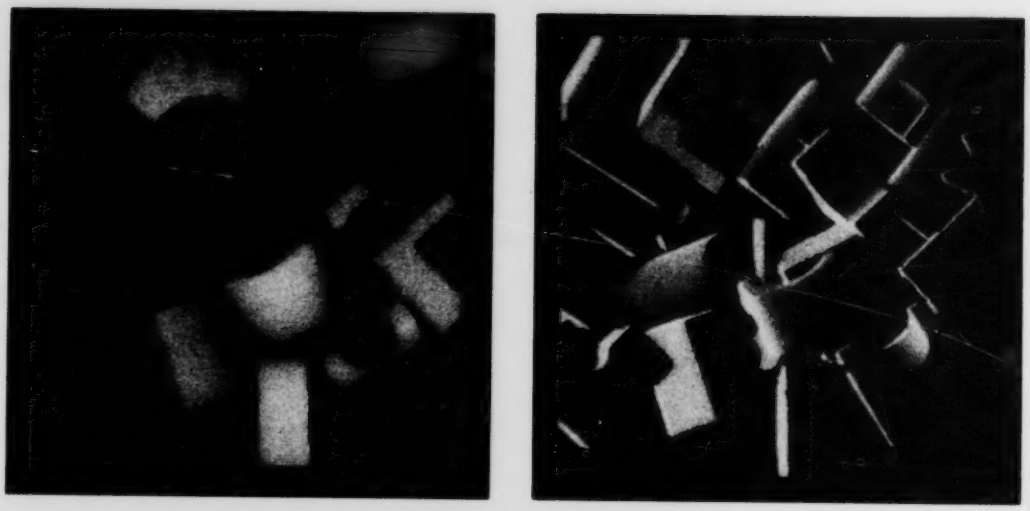
CAT # 093, BLOC 28

$\Delta x = \Delta y = 0.8$ mm



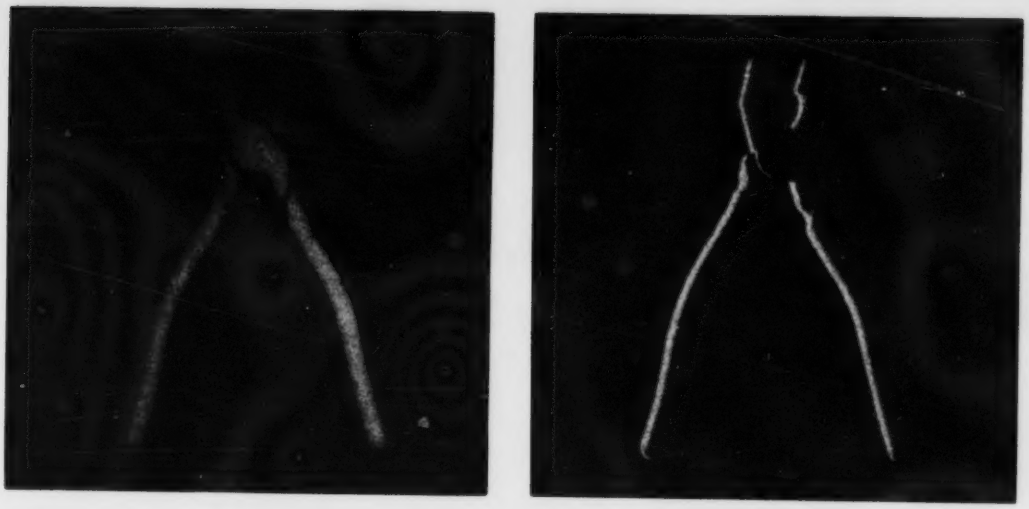
CAT # 092, BLOC 29

$\Delta x = \Delta y = 0.8$ mm



CAT # 094, BLOC 30

$\Delta x = \Delta y = 0.8$ mm

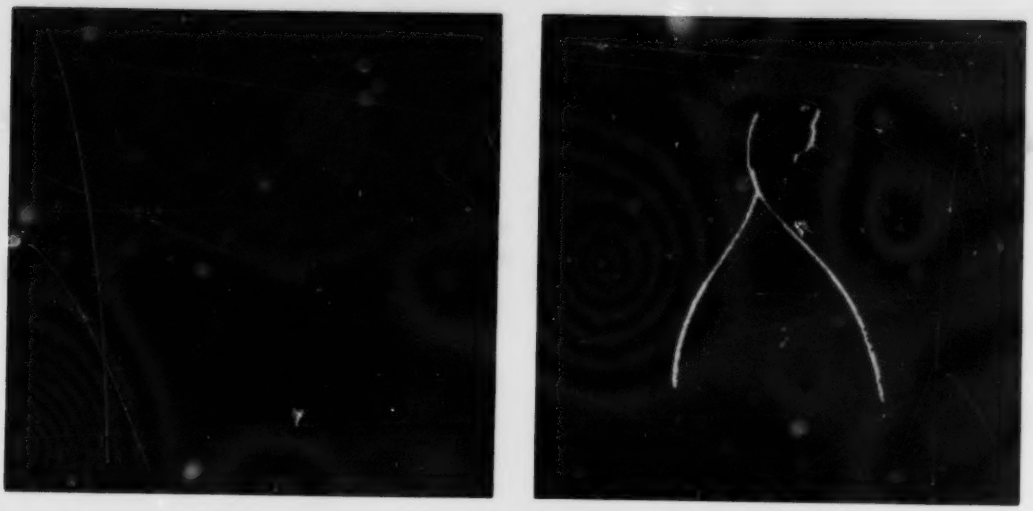


CAT # 062, TOOL 1

$\Delta x = \Delta y = 0.9$ mm

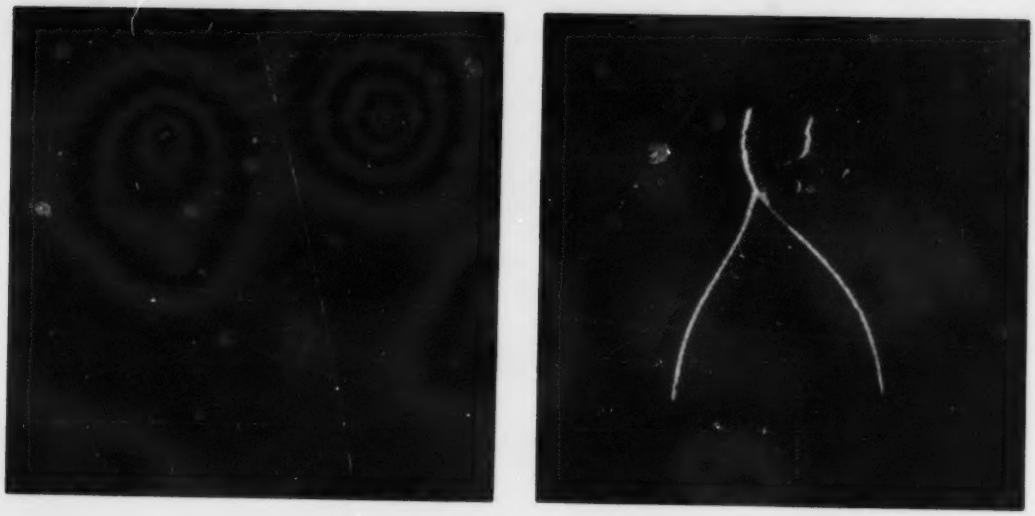
CAT # 063, TOOL 2

$\Delta x = \Delta y = 0.9$ mm



CAT # 064, TOOL 3

$\Delta x = \Delta y = 0.9$ mm



CAT # 065, TOOL 4

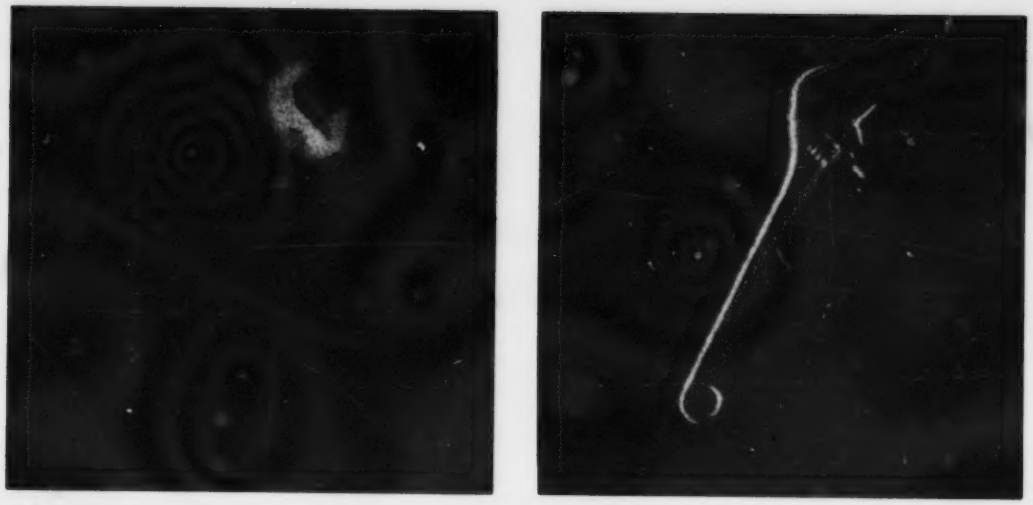
$\Delta x = \Delta y = 0.9$ mm

CAT # 066, TOOL 5

$\Delta x = \Delta y = 0.9$ mm

CAT # 067, TOOL 6

$\Delta x = \Delta y = 0.9$ mm



CAT # 068, TOOL 7

$\Delta x = \Delta y = 0.9$ mm

CAT # 069, TOOL 8

$\Delta x = \Delta y = 0.9$ mm

CAT # 070, TOOL 9

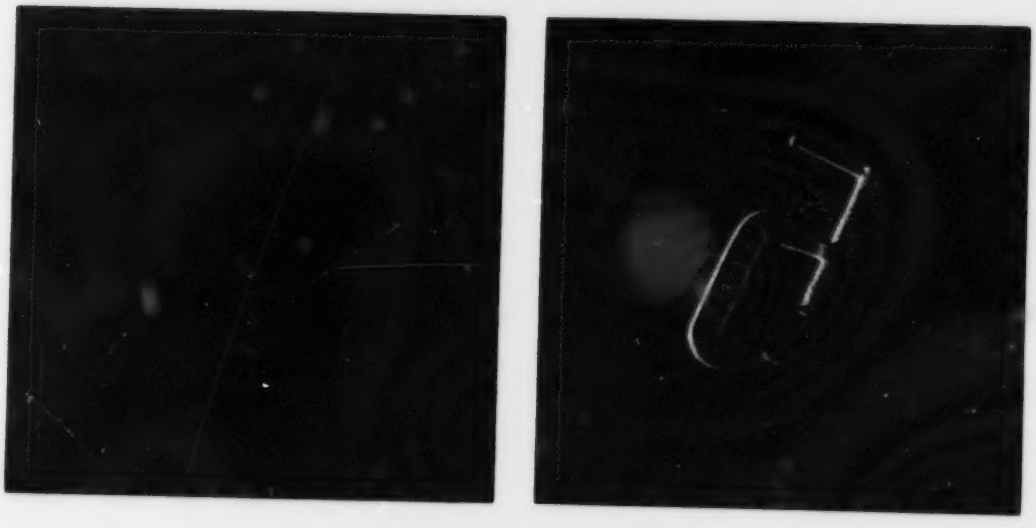
$\Delta x = \Delta y = 0.9$ mm

CAT # 071, TOOL 10

$\Delta x = \Delta y = 0.9$ mm

CAT # 072, TOOL 11

$\Delta x = \Delta y = 0.9$ mm

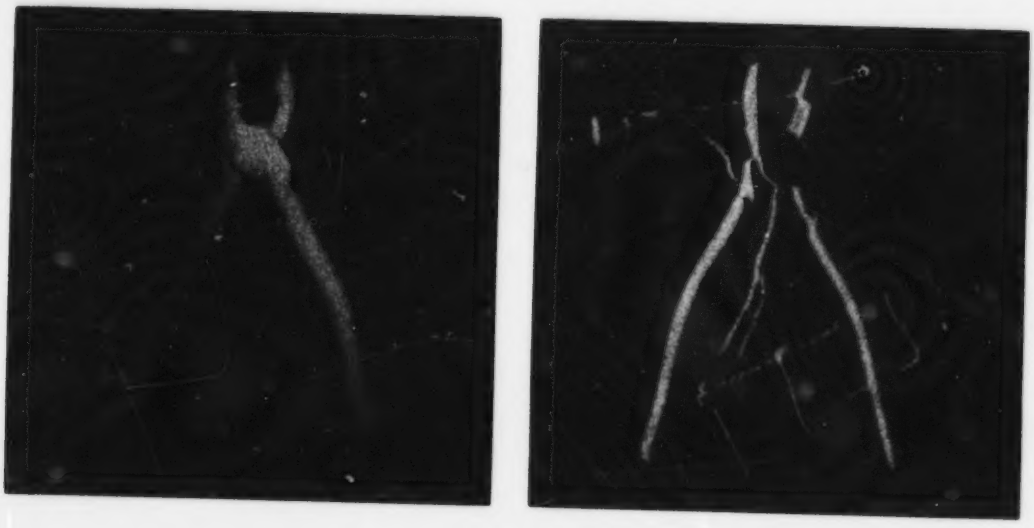


CAT # 073, TOOL 12

$\Delta x = \Delta y = 0.9$ mm

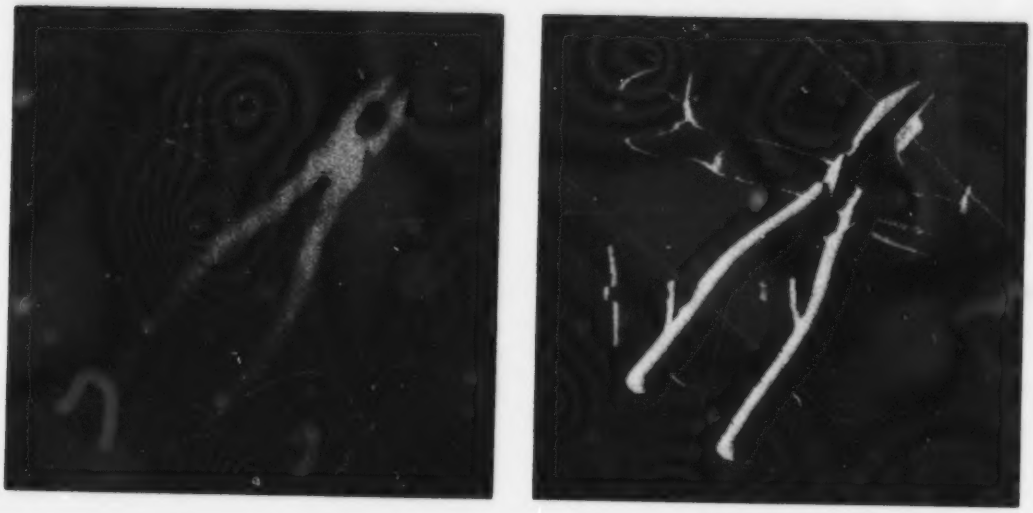
CAT # 075, TOOL 13

$\Delta x = \Delta y = 0.9$ mm



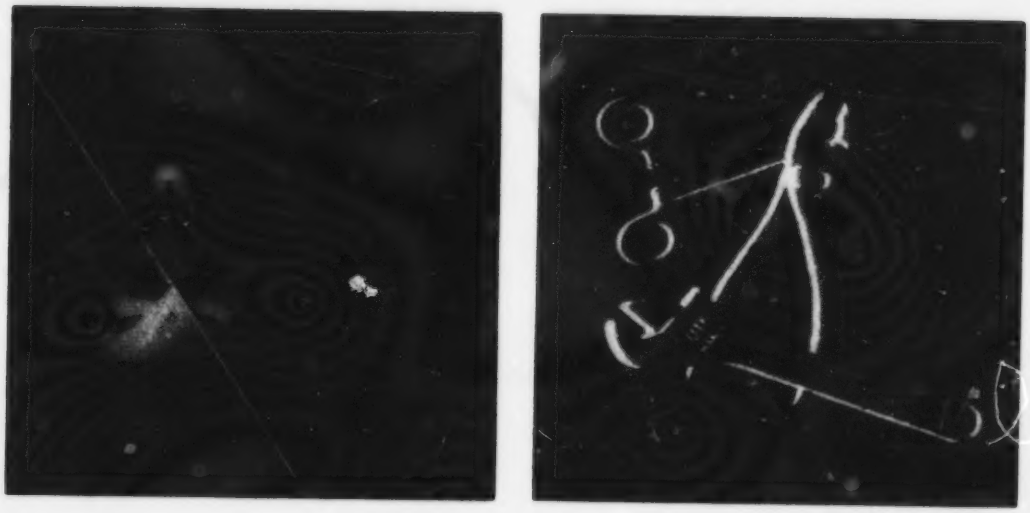
CAT # 076, TOOL 14

$\Delta x = \Delta y = 0.9$ mm



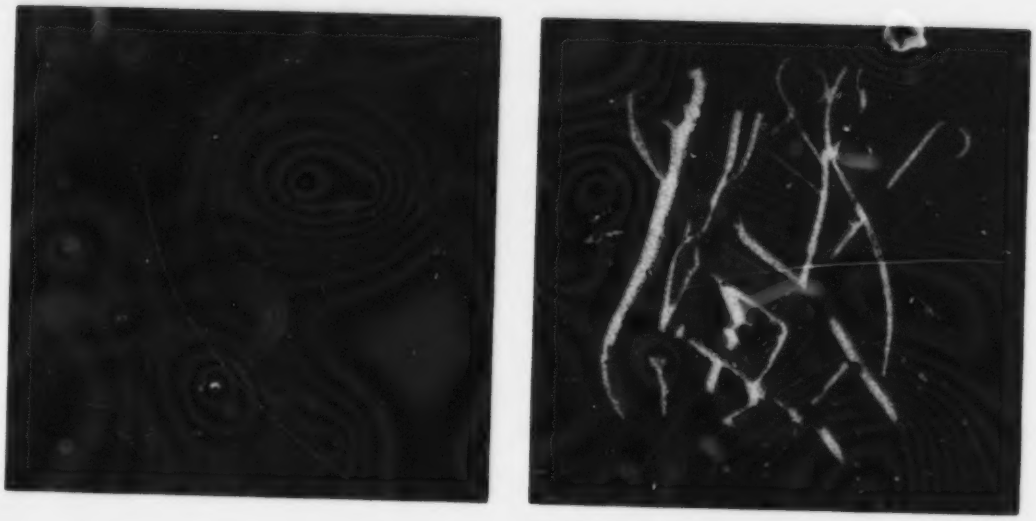
CAT # 077, TOOL 15

$\Delta x = \Delta y = 0.9$ mm



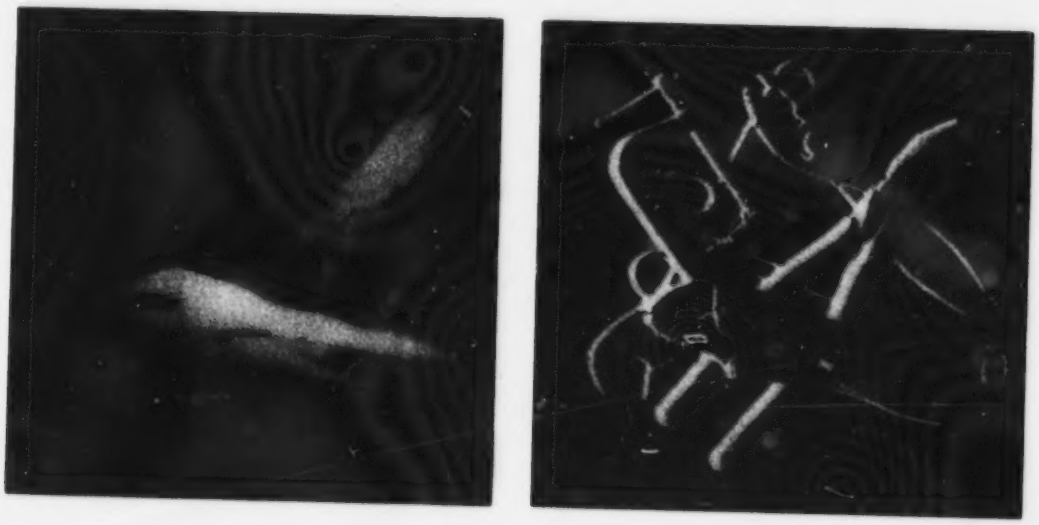
CAT # 078, TOOL 16

$\Delta x = \Delta y = 0.9$ mm



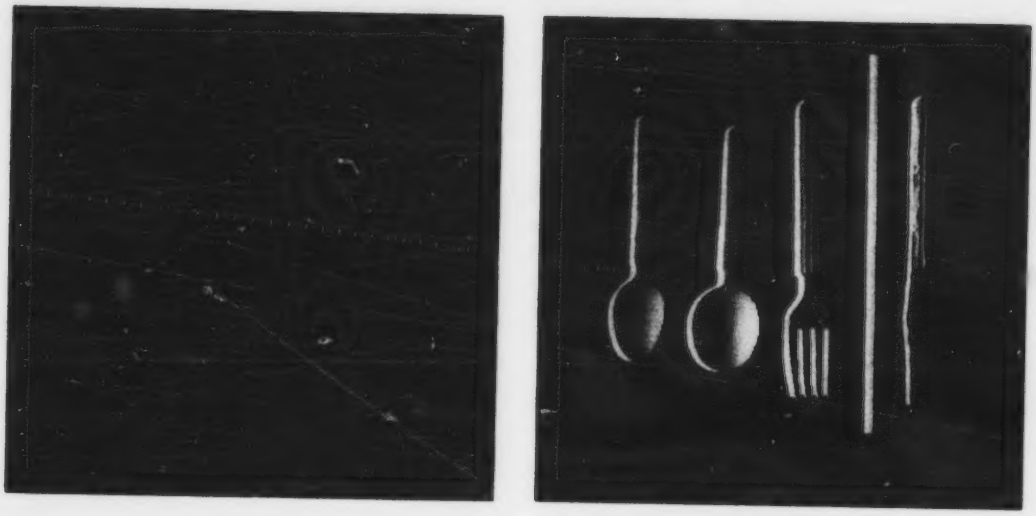
CAT # 079, TOOL 17

$\Delta x = \Delta y = 0.9$ mm



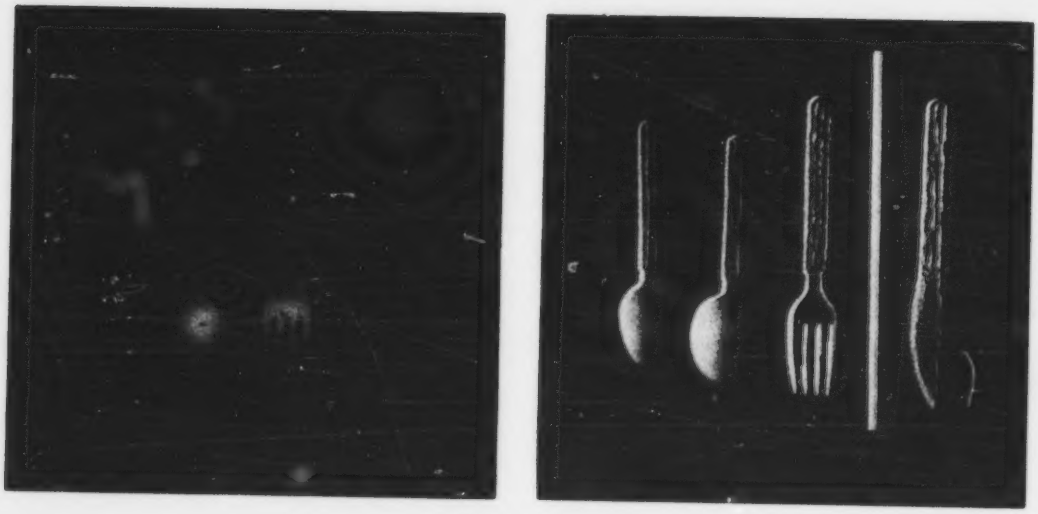
CAT # 080, TOOL 18

$\Delta x = \Delta y = 0.9$ mm



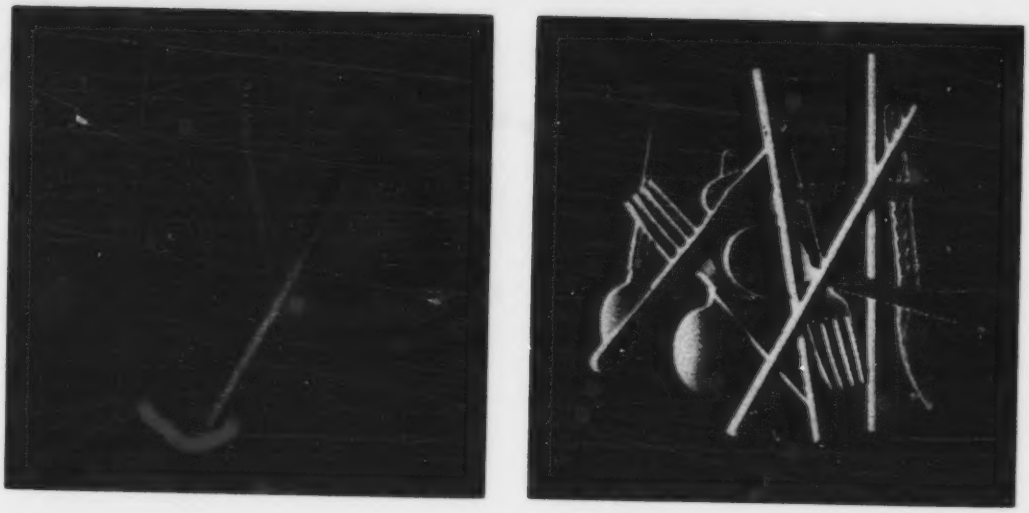
CAT # 023, UTEN 1

$\Delta x = \Delta y = 0.9$ mm



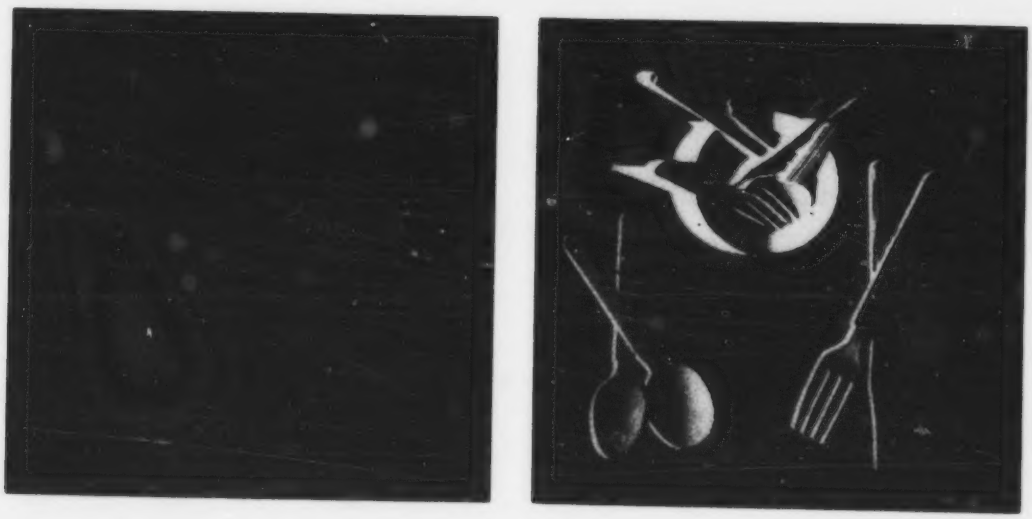
CAT # 024, UTEN 2

$\Delta x = \Delta y = 0.9$ mm



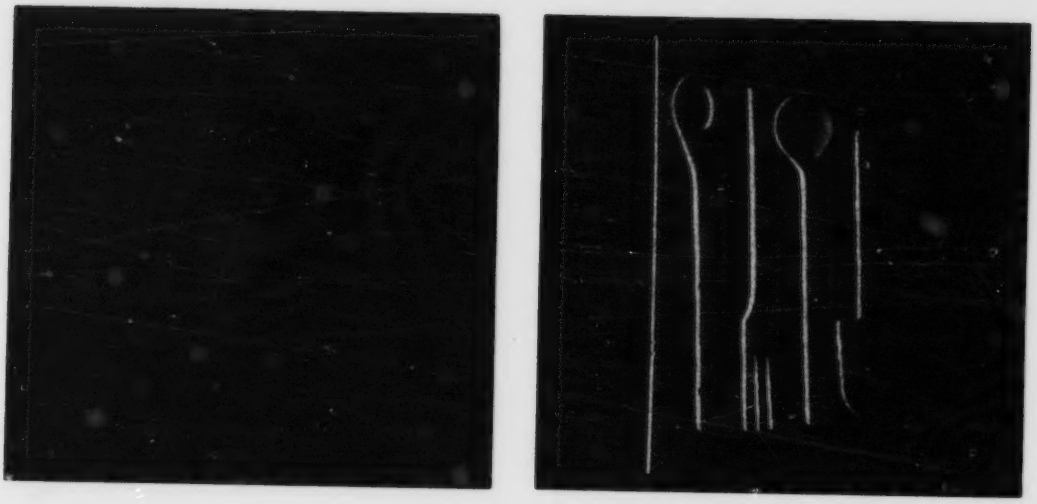
CAT # 025, UTEN 3

$\Delta x = \Delta y = 0.9$ mm



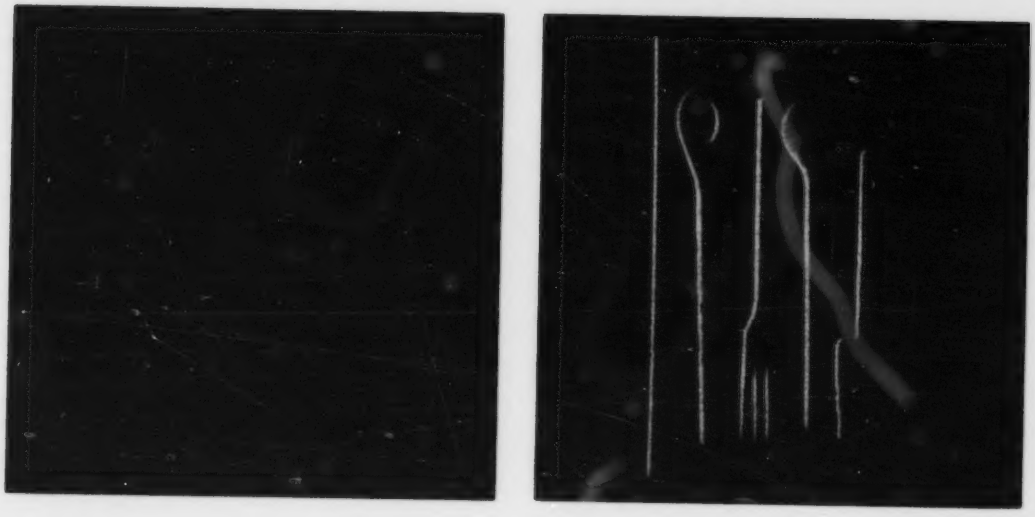
CAT # 022, UTEN 4

$\Delta x = \Delta y = 0.9$ mm



CAT # 240, UTEN 5

$\Delta x = \Delta y = 1.5$ mm



CAT # 241, UTEN 6

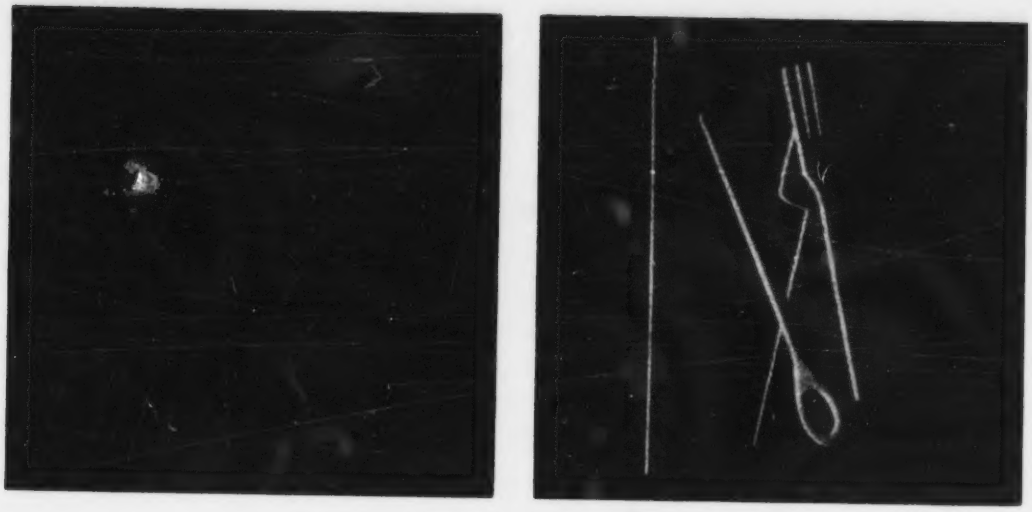
$\Delta x = \Delta y = 1.5$ mm

CAT # 242, UTEN 7

$\Delta x = \Delta y = 1.5$ mm

CAT # 243, UTEN 8

$\Delta x = \Delta y = 1.5$ mm



CAT # 245, UTEN 9

$\Delta x = \Delta y = 1.5$ mm

CAT # 246, UTEN 10

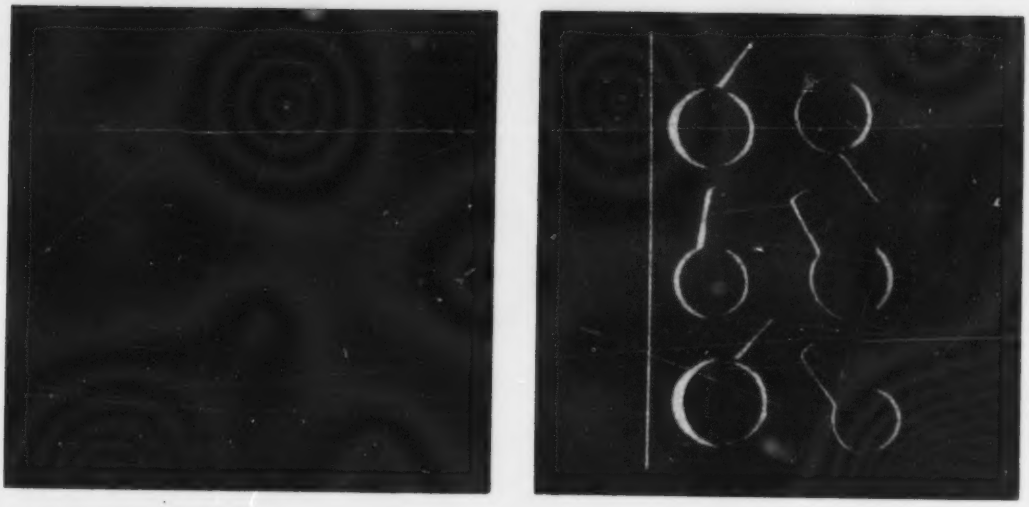
$\Delta x = \Delta y = 1.5$ mm

CAT # 236, UTEN 11

$\Delta x = \Delta y = 0.9$ mm

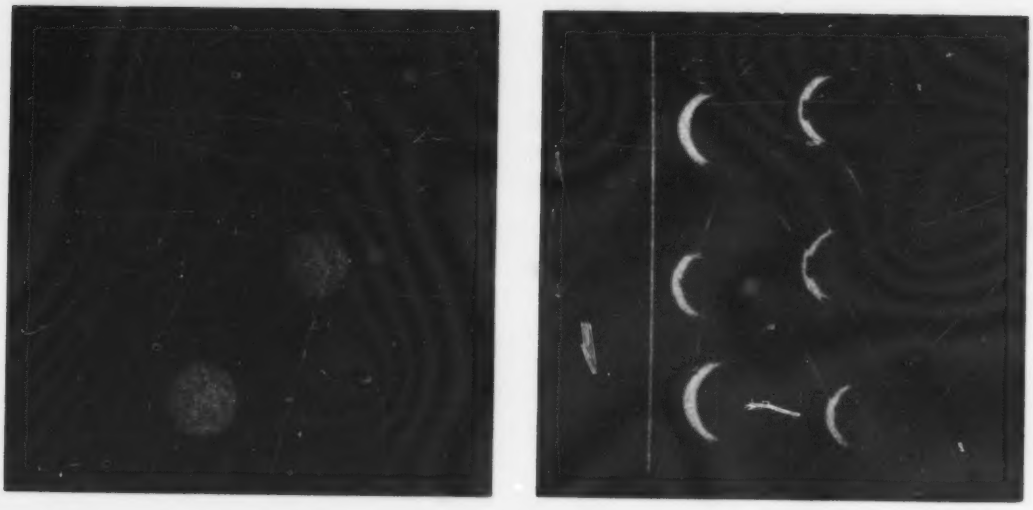
CAT # 237, UTEN 12

$\Delta x = \Delta y = 0.9$ mm



CAT # 238, UTEN 13

$\Delta x = \Delta y = 1.5$ mm

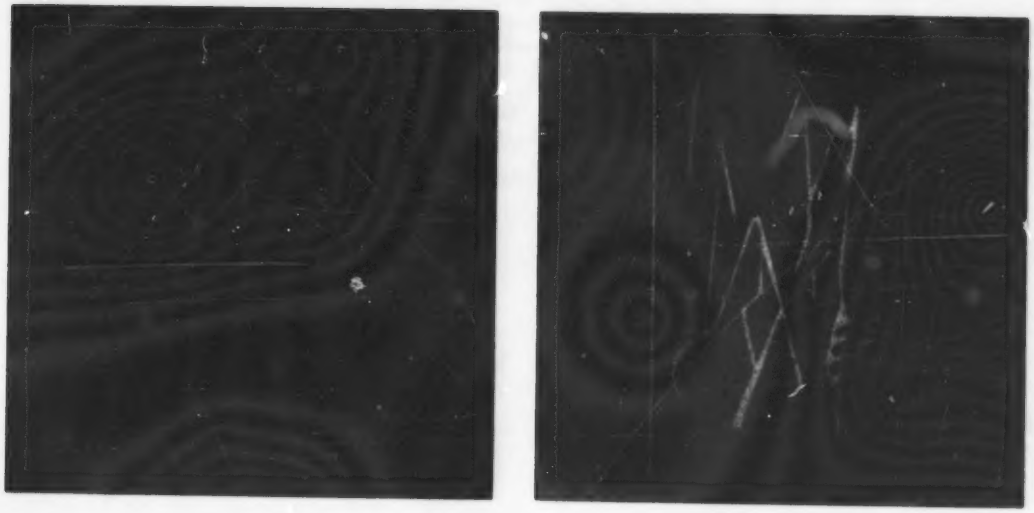


CAT # 239, UTEN 14

$\Delta x = \Delta y = 1.5$ mm

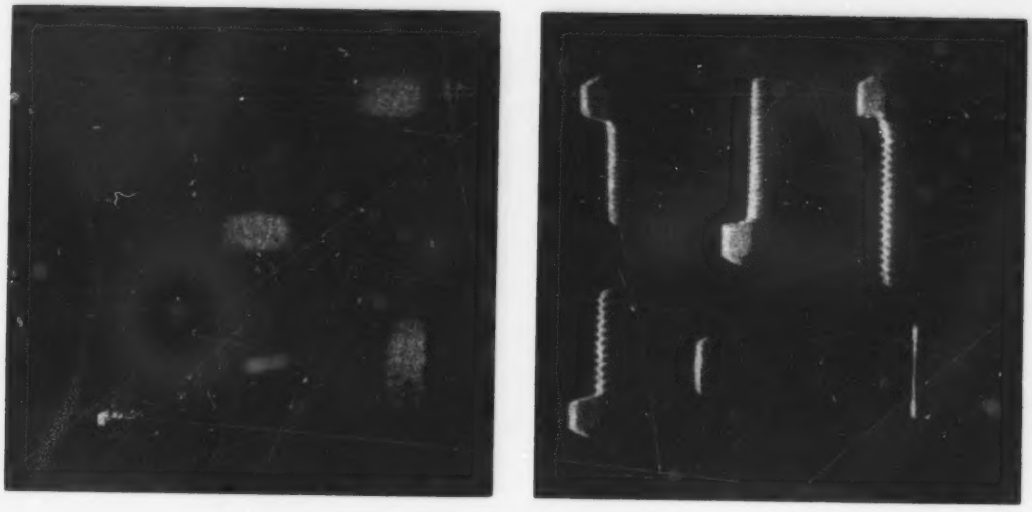
CAT # 247, UTEN 15

$\Delta x = \Delta y = 1.5$ mm



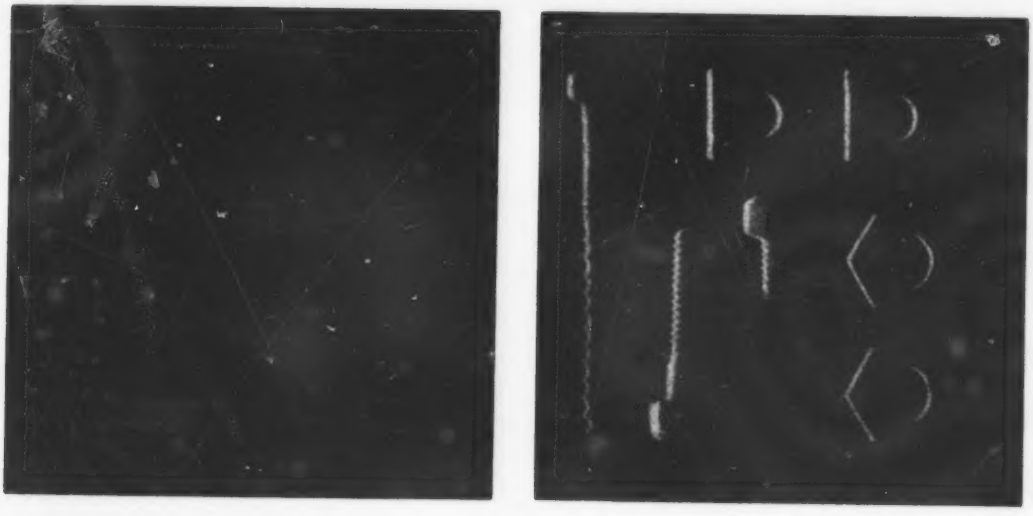
CAT # 244, UTEN 16

$\Delta x = \Delta y = 1.5$ mm



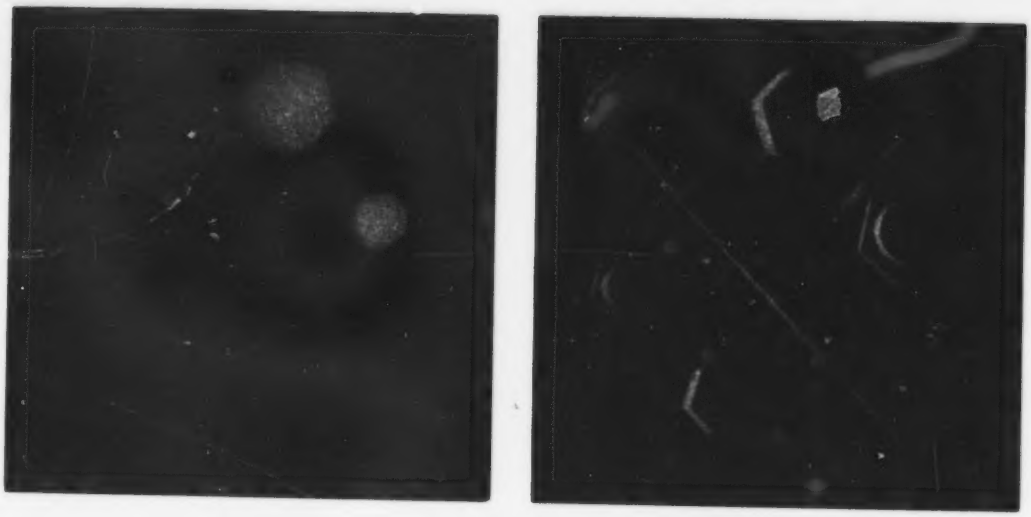
CAT # 050, BOLT 1

$\Delta x = \Delta y = 0.5$ mm



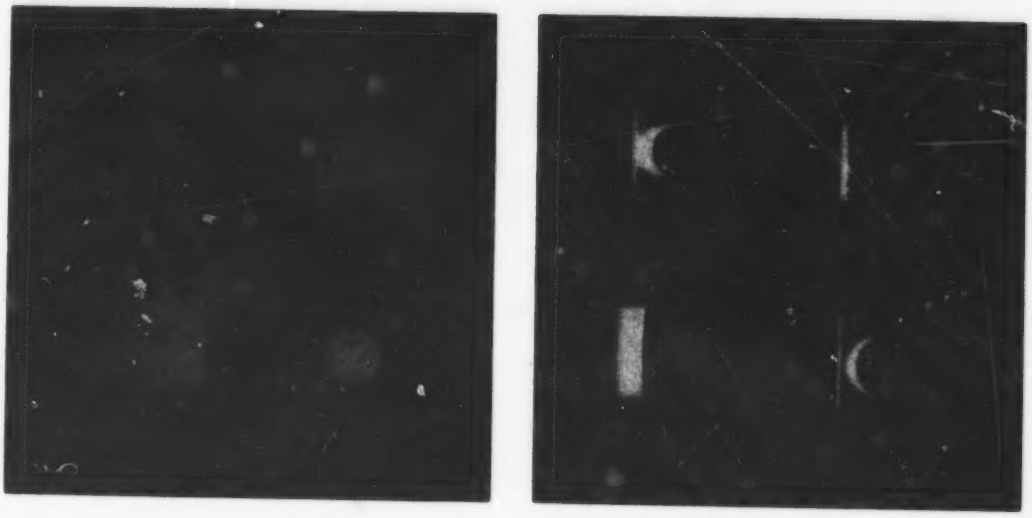
CAT # 051, BOLT 2

$\Delta x = \Delta y = 0.5$ mm



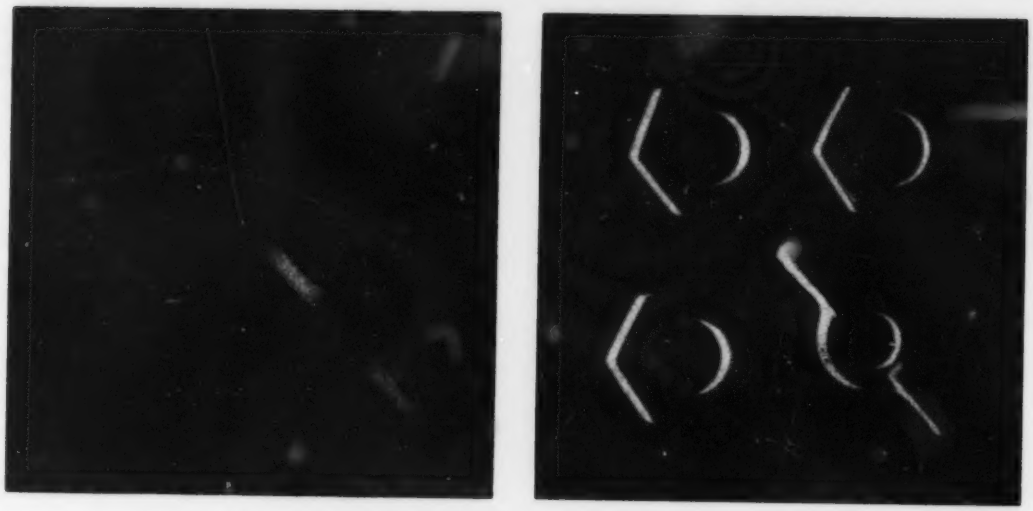
CAT # 052, BOLT 3

$\Delta x = \Delta y = 0.5$ mm



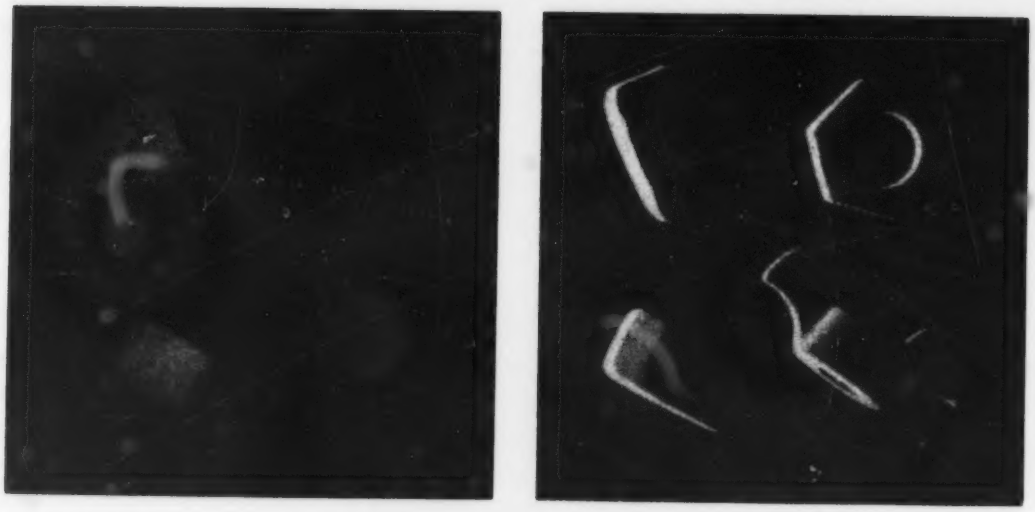
CAT # 053, BOLT 4

$\Delta x = \Delta y = 0.5$ mm



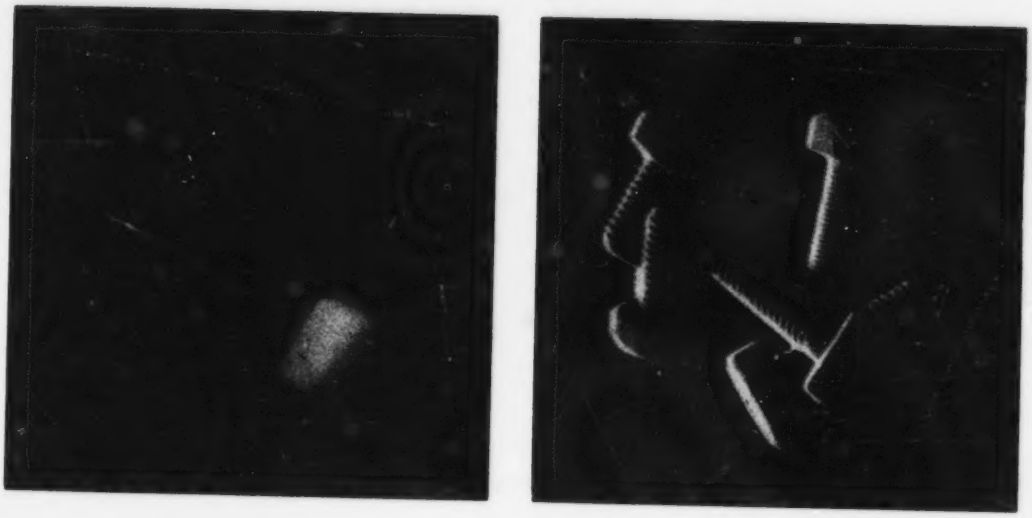
CAT # 254, BOLT 5

$\Delta x = \Delta y = 0.5$ mm



CAT # 255, BOLT 6

$\Delta x = \Delta y = 0.5$ mm

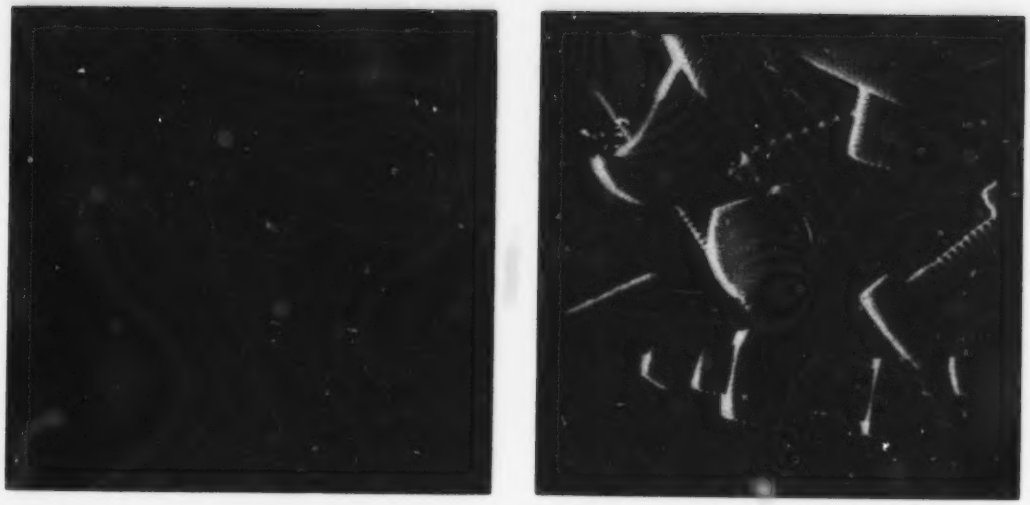


CAT # 049, BOLT 7

$\Delta x = \Delta y = 0.5$ mm

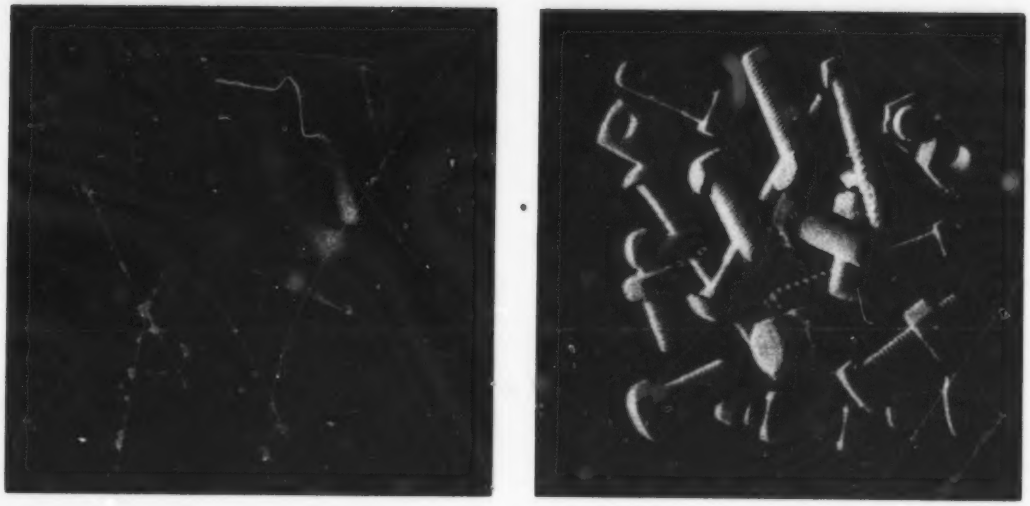
CAT # 054, BOLT 7

$\Delta x = \Delta y = 0.5$ mm



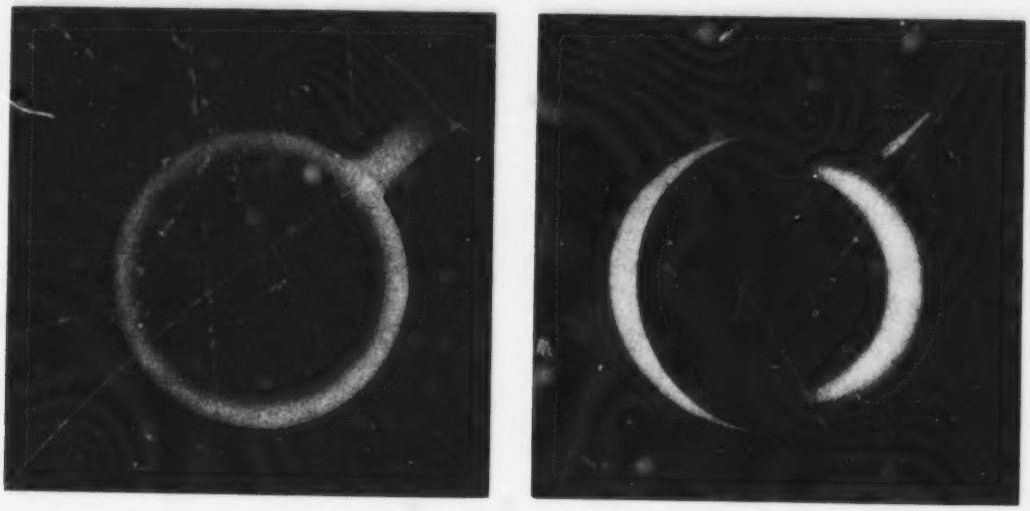
CAT # 059, BOLT 9

$\Delta x = \Delta y = 0.5$ mm



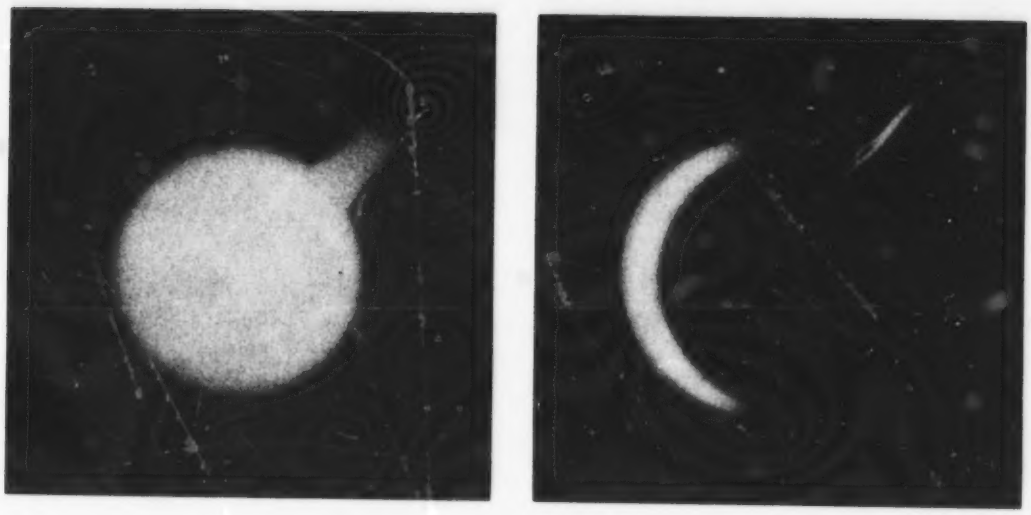
CAT # 060, BOLT 10

$\Delta x = \Delta y = 0.9$ mm



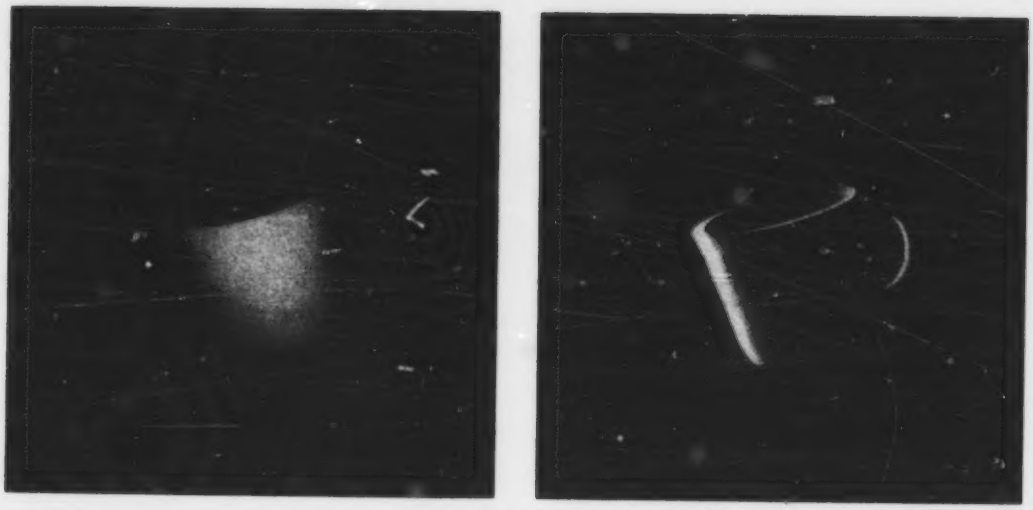
CAT # 258, CUP 1

$\Delta x = \Delta y = 0.5$ mm



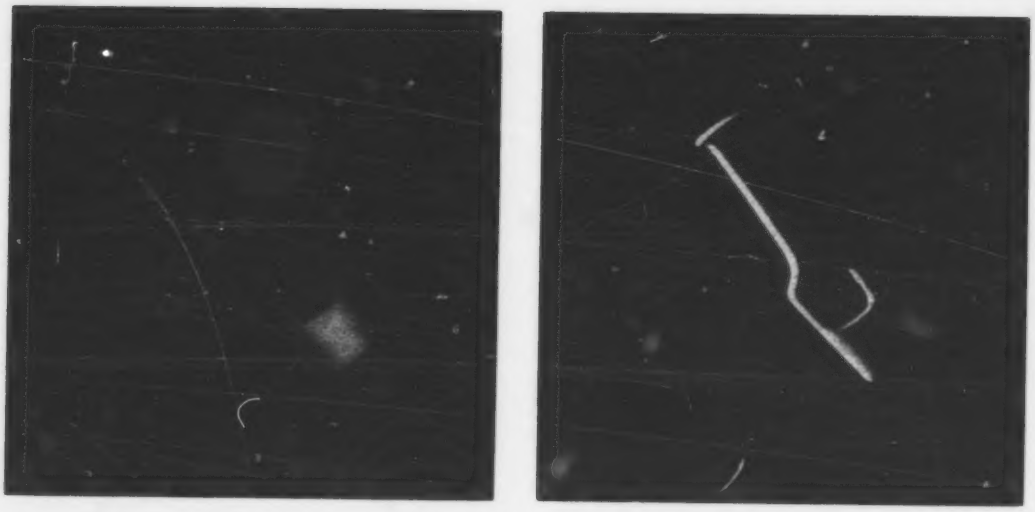
CAT # 259, CUP 2

$\Delta x = \Delta y = 0.5$ mm



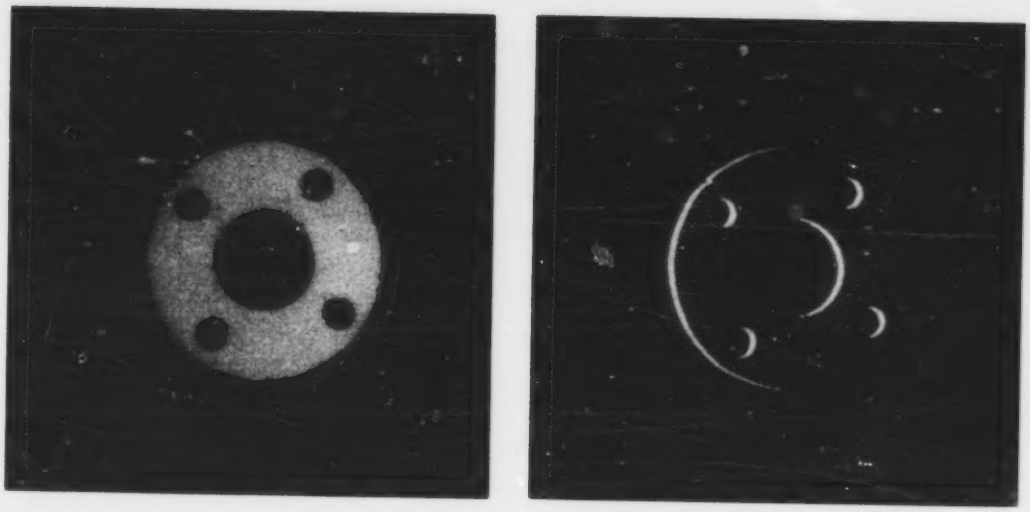
CAT # 268, CUP 3

$\Delta x = \Delta y = 0.9$ mm



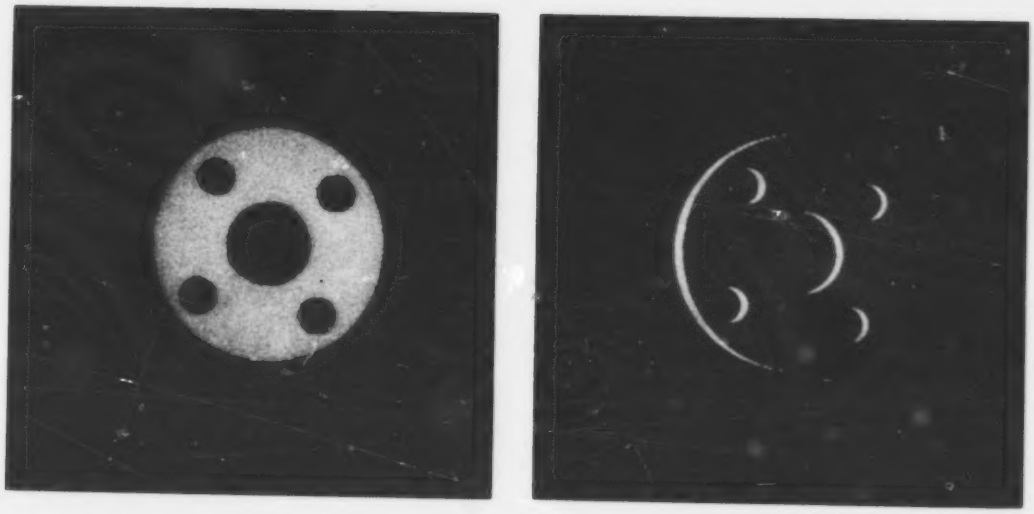
CAT # 275, MECA 1

$\Delta x = \Delta y = 0.9$ mm



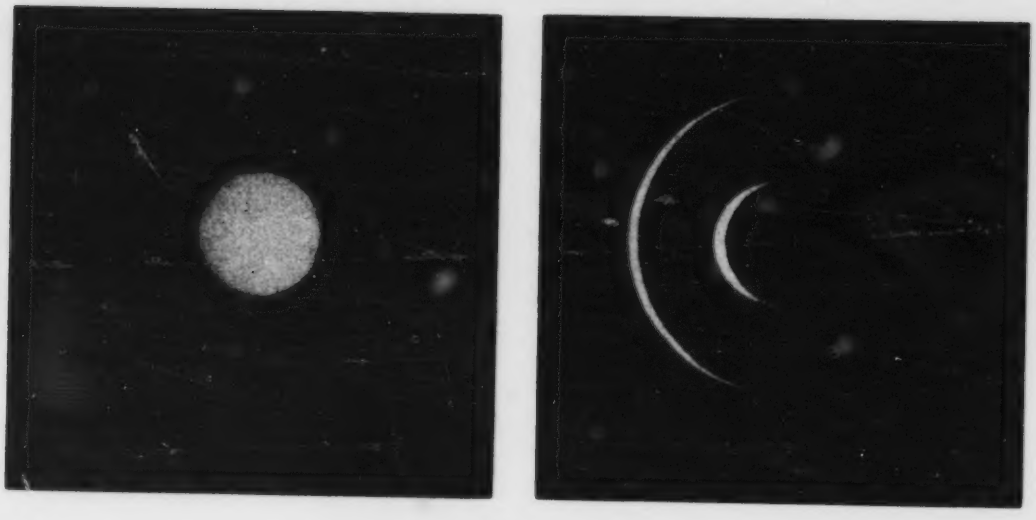
CAT # 273, MECA 2

$\Delta x = \Delta y = 0.9$ mm



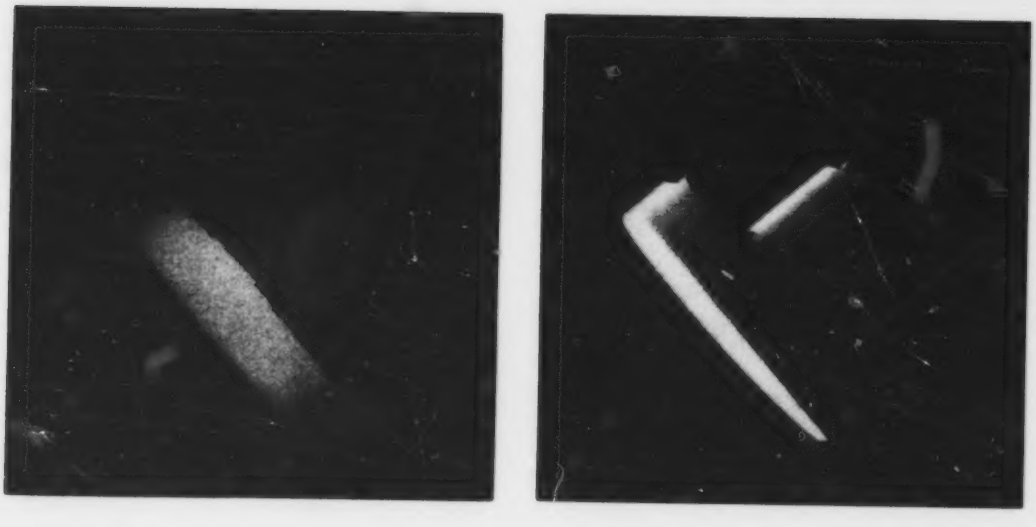
CAT # 274, MECA 3

$\Delta x = \Delta y = 0.9$ mm



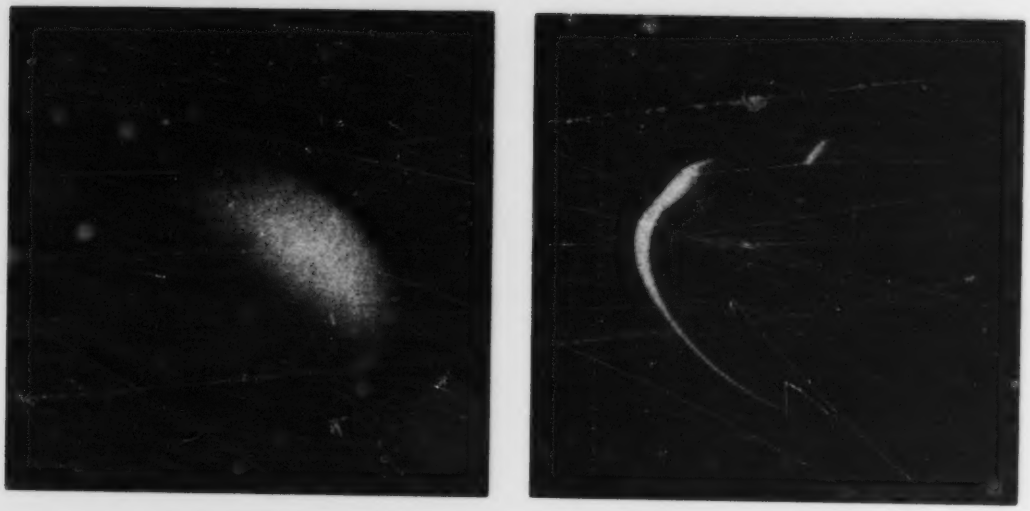
CAT # 269, MECA 4

$\Delta x = \Delta y = 0.5$ mm



CAT # 270, MECA 5

$\Delta x = \Delta y = 0.5$ mm

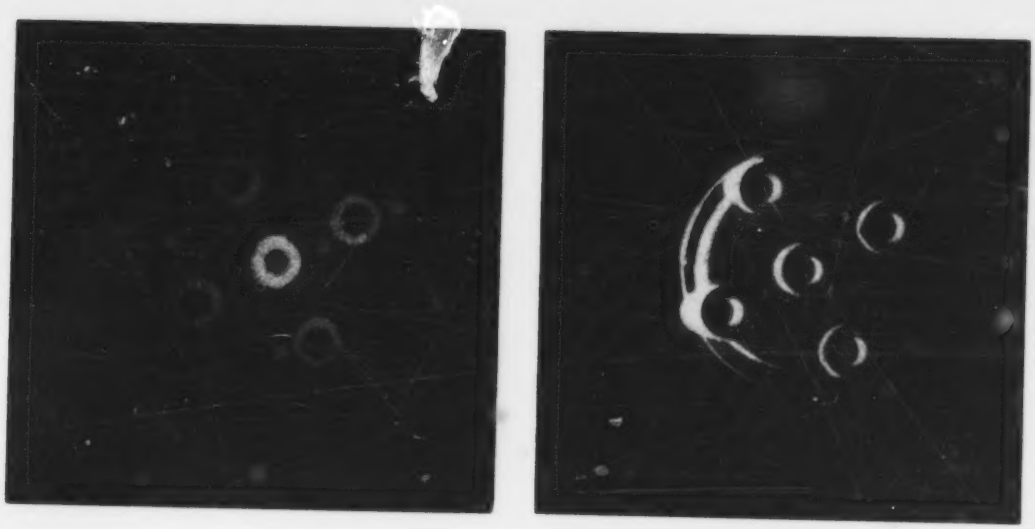


CAT # 271, MECA 6

$\Delta x = \Delta y = 0.5$ mm

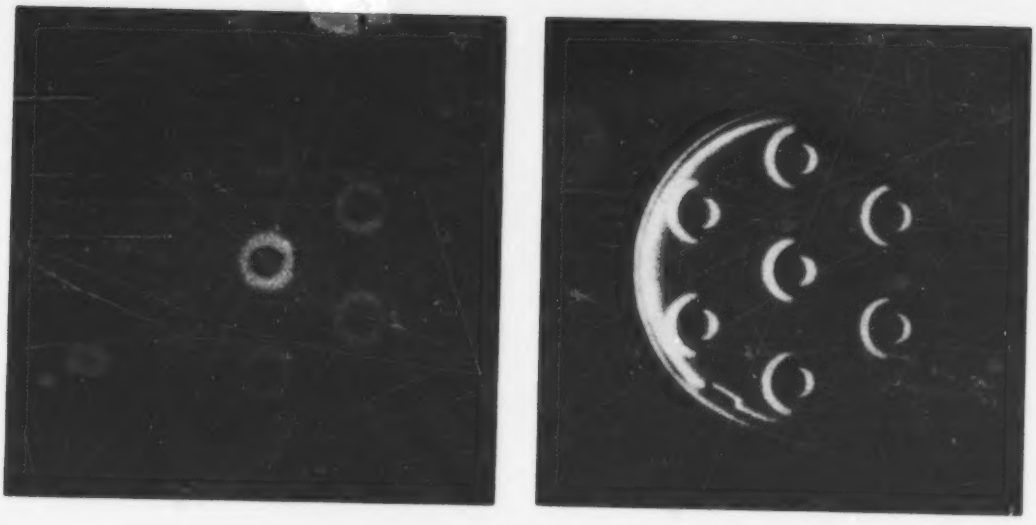
CAT # 272, MECA 7

$\Delta x = \Delta y = 0.9$ mm



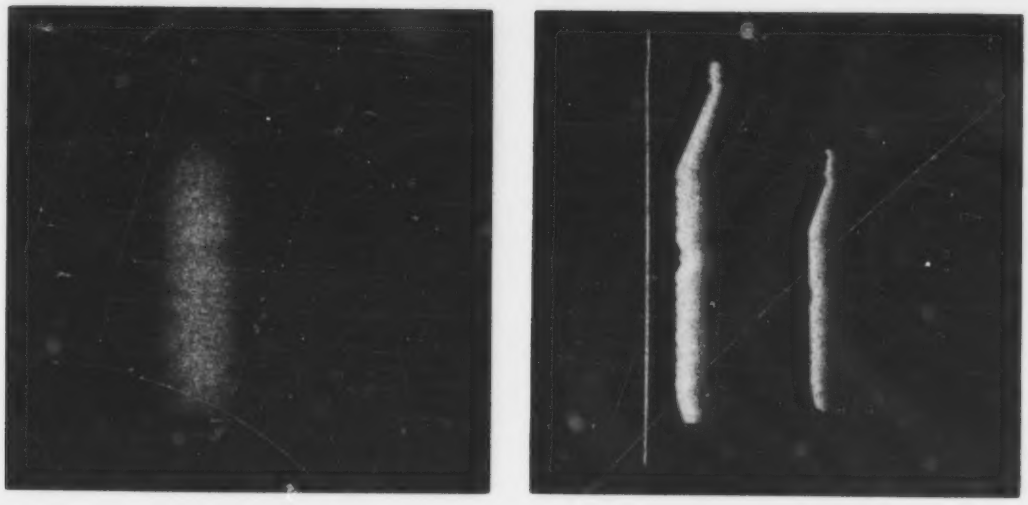
CAT # 261, MECA 8

$\Delta x = \Delta y = 0.5$ mm



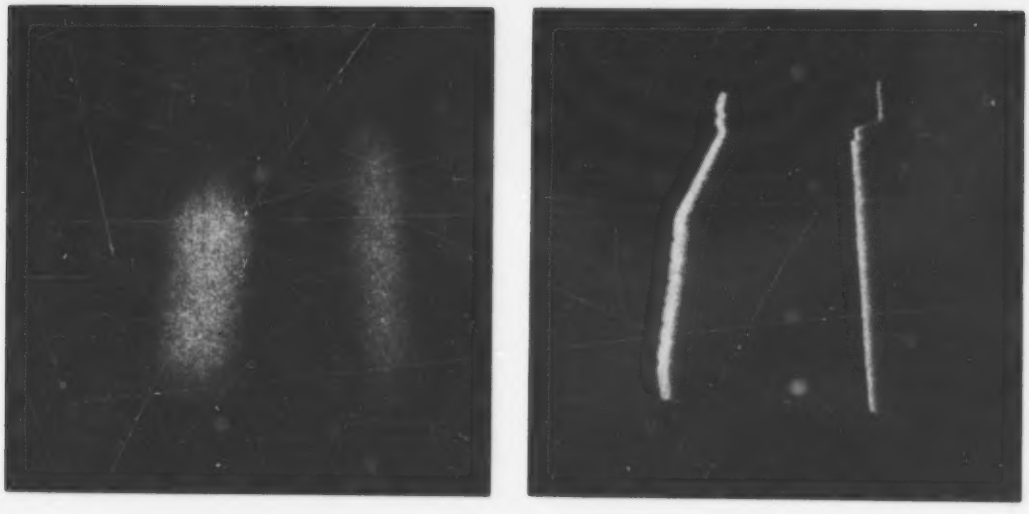
CAT # 260, MECA 9

$\Delta x = \Delta y = 0.5$ mm



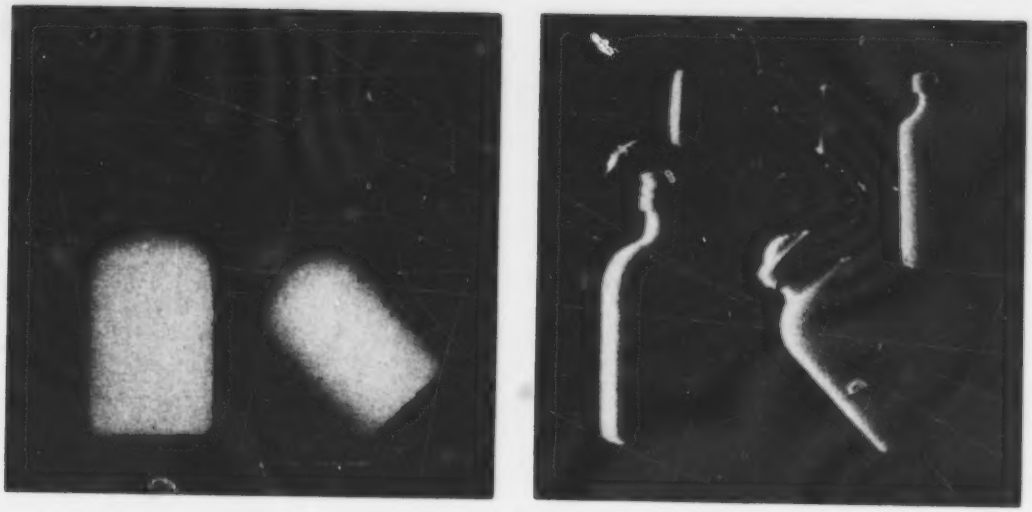
CAT # 265, MECA 10

$\Delta x = \Delta y = 1.5$ mm



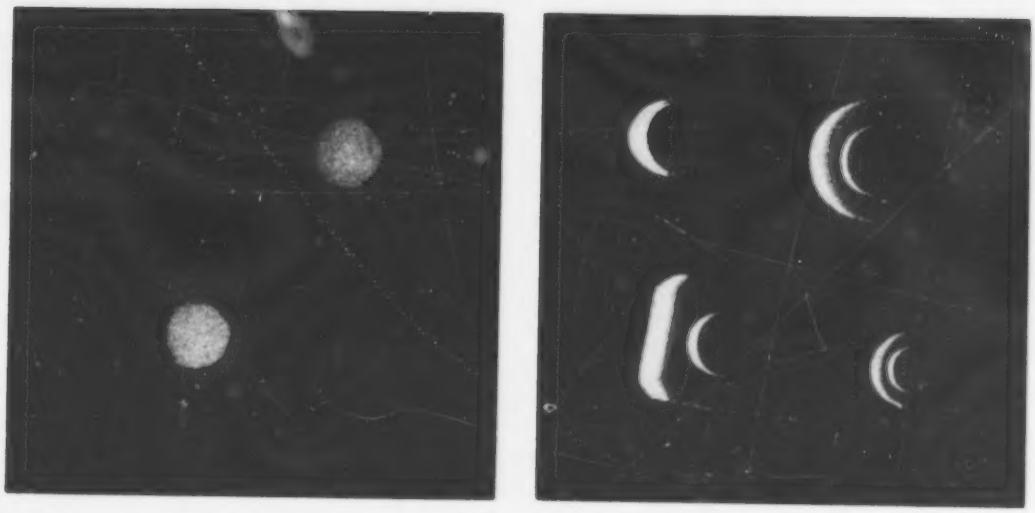
CAT # 264, MECA 11

$\Delta x = \Delta y = 0.9$ mm



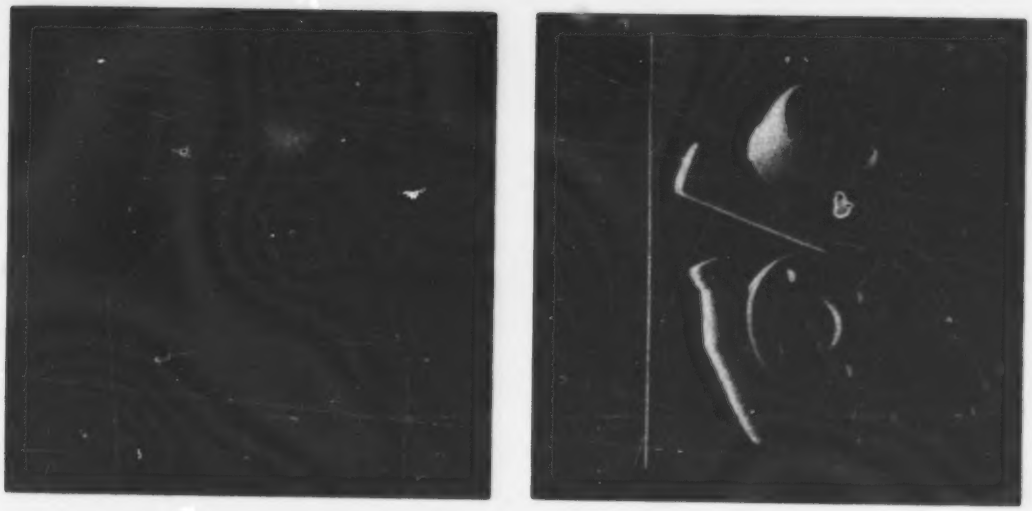
CAT # 262, MECA 12

$\Delta x = \Delta y = 0.5$ mm



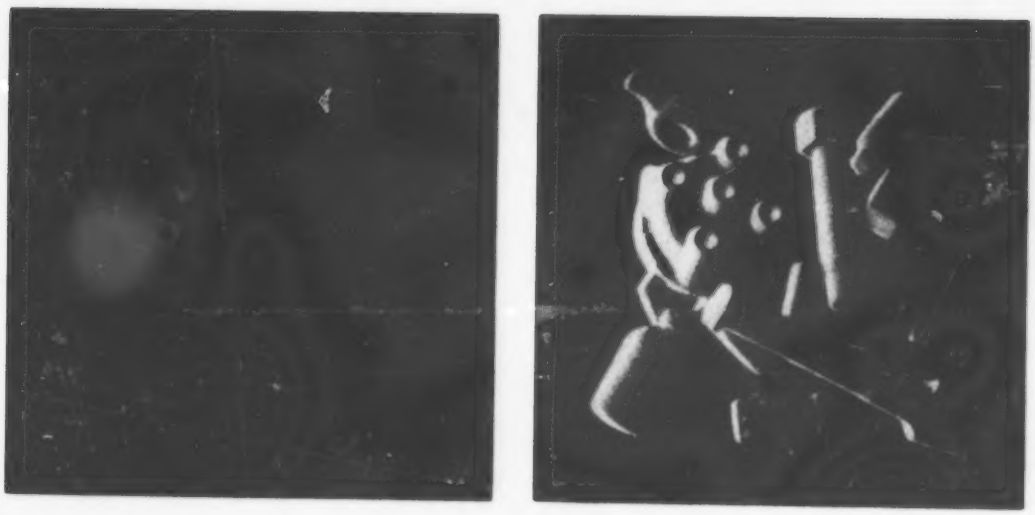
CAT # 263, MECA 13

$\Delta x = \Delta y = 0.5$ mm



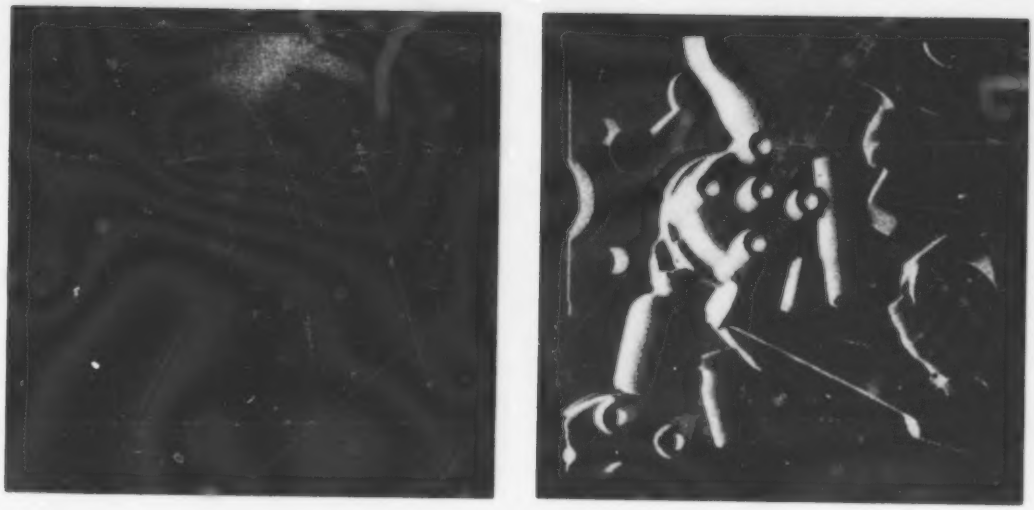
CAT # 276, MECA 14

$\Delta x = \Delta y = 1.5$ mm



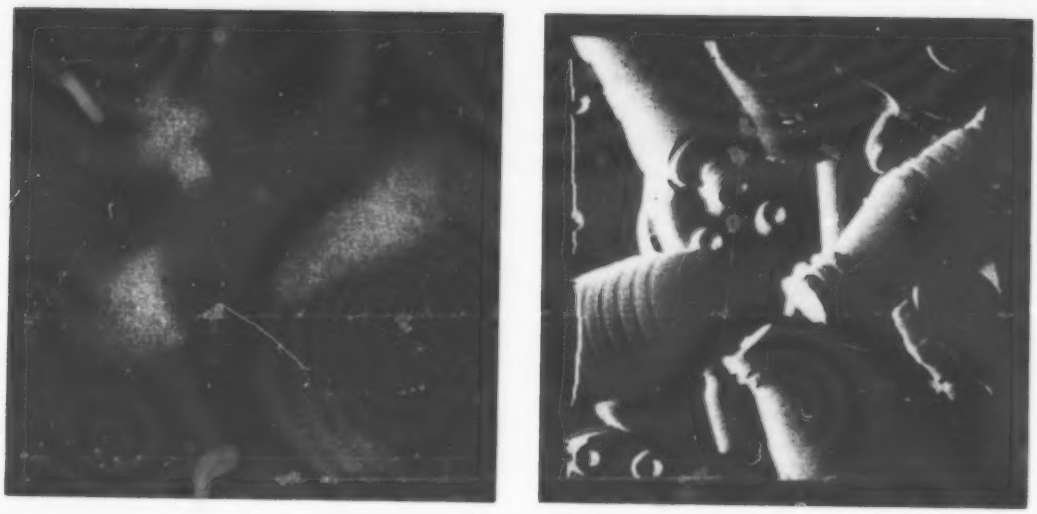
CAT # 279, MECA 15

$\Delta x = \Delta y = 0.9$ mm



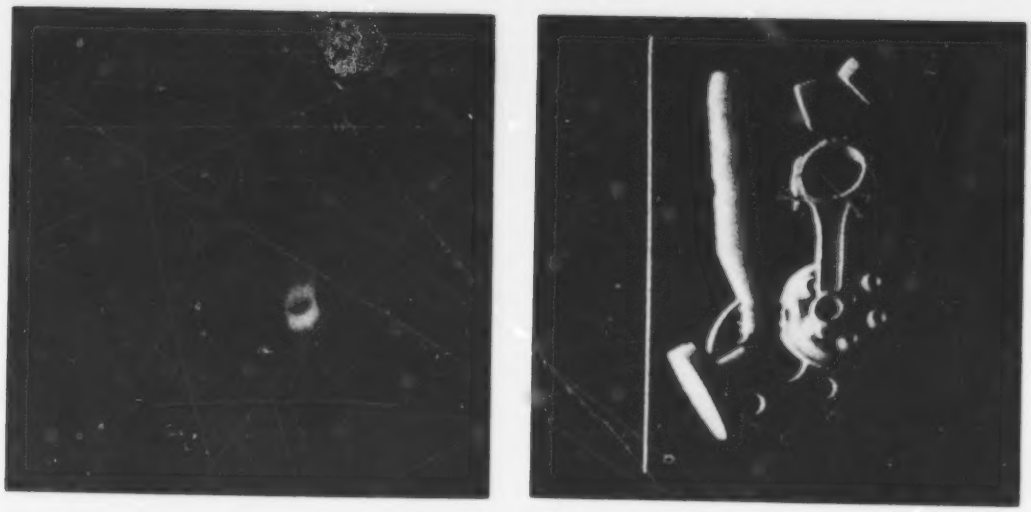
CAT # 282, MECA 16

$\Delta x = \Delta y = 0.9$ mm



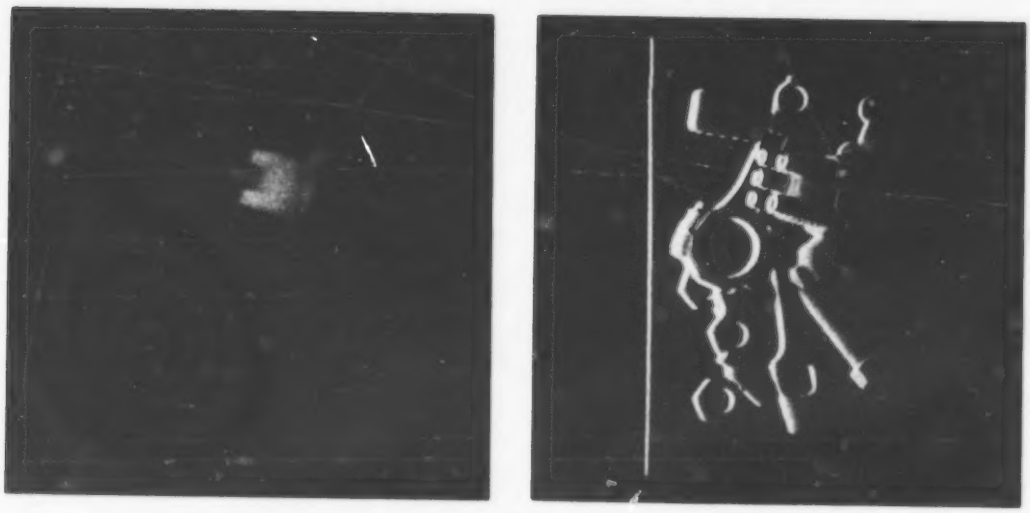
CAT # 281, MECA 17

$\Delta x = \Delta y = 0.9$ mm



CAT # 277, MECA 18

$\Delta x = \Delta y = 1.5$ mm

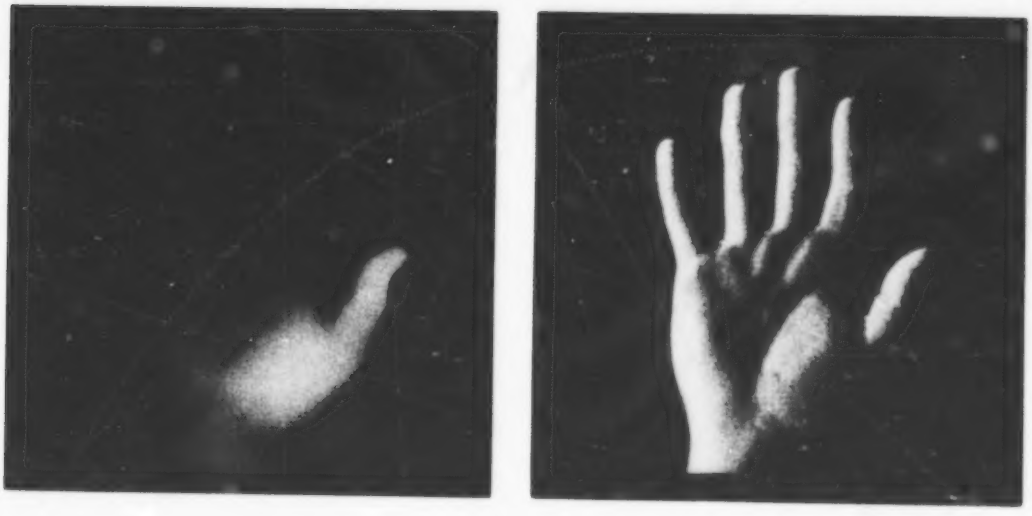


CAT # 278, MECA 19

$\Delta x = \Delta y = 1.5$ mm

CAT # 016, HAND 1

$\Delta x = \Delta y = 0.9$ mm



CAT # 018, HAND 2

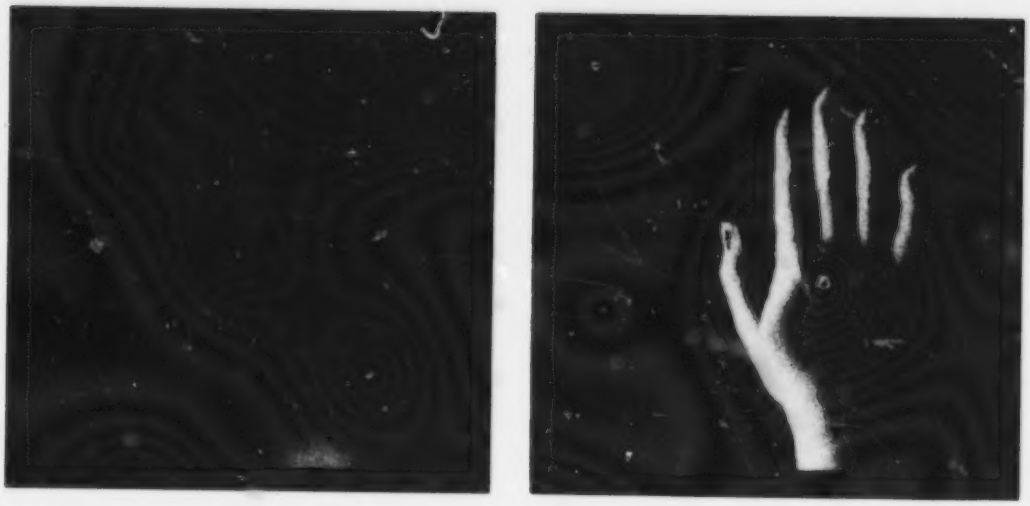
$\Delta x = \Delta y = 0.9$ mm

CAT # 019, HAND 3

$\Delta x = \Delta y = 0.9$ mm

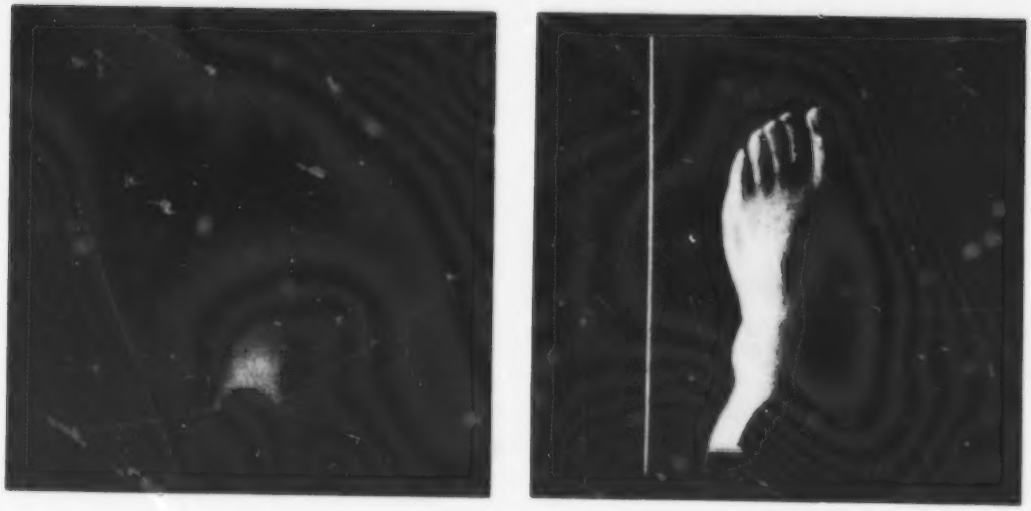
CAT # 020, HAND 4

$\Delta x = \Delta y = 0.9$ mm



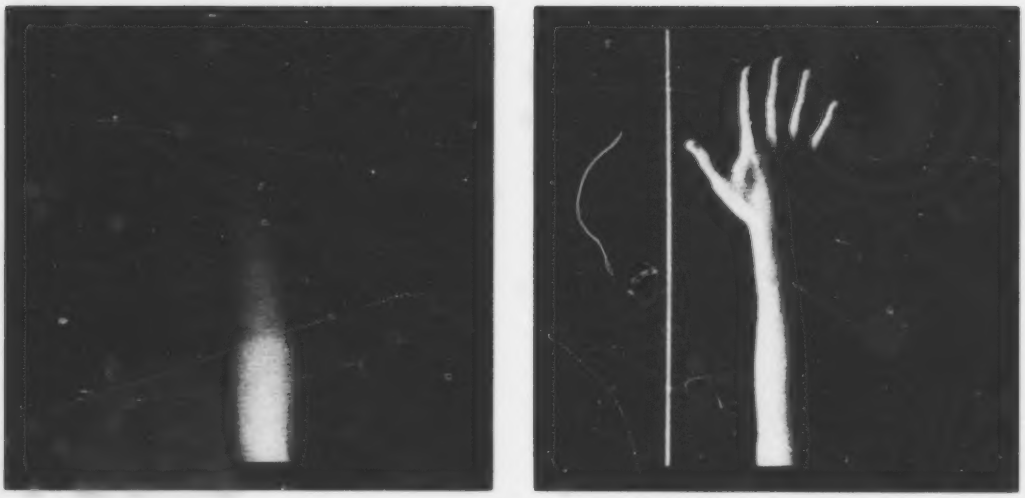
CAT # 011, HAND 5

$\Delta x = \Delta y = 0.9$ mm



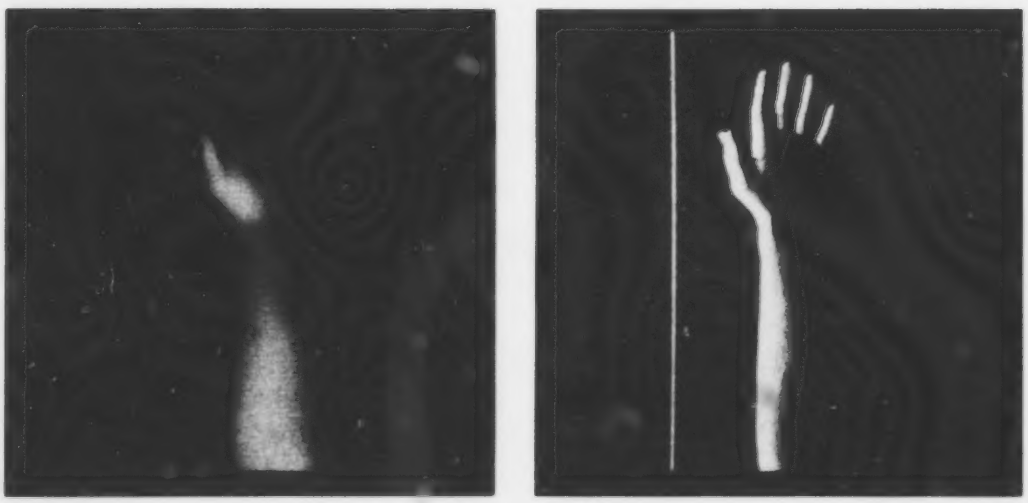
CAT # 230, FOOT 1

$\Delta x = \Delta y = 1.5$ mm



CAT # 228, ARM 1

$\Delta x = \Delta y = 2.0$ mm



CAT # 229, ARM 2

$\Delta x = \Delta y = 2.0$ mm

CAT # 402, FACE 1

$\Delta x = \Delta y = 1.2$ mm

CAT # 401, FACE 2

$\Delta x = \Delta y = 1.2$ mm

CAT # 385, FACE 3

$\Delta x = \Delta y = 1.2$ mm

CAT # 386, FACE 4

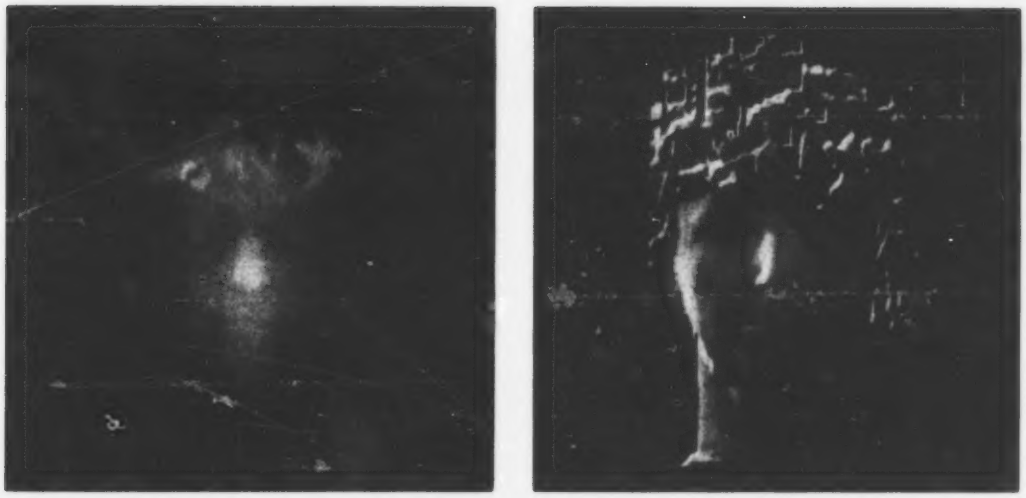
$\Delta x = \Delta y = 1.2$ mm

CAT # 413, FACE 5

$\Delta x = \Delta y = 1.2$ mm

CAT # 405, FACE 6

$\Delta x = \Delta y = 1.2$ mm

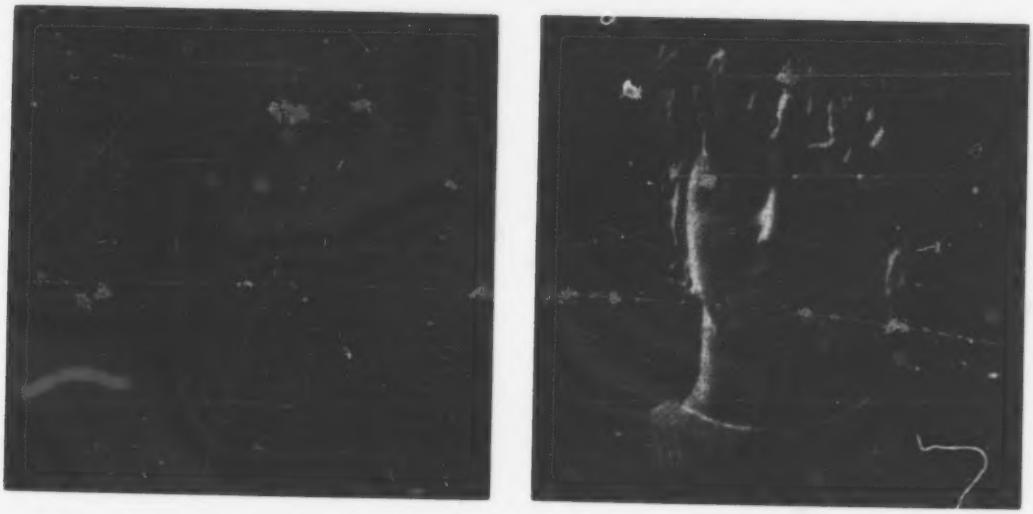


CAT # 393, FACE 7

$\Delta x = \Delta y = 1.2$ mm

CAT # 390, FACE 8

$\Delta x = \Delta y = 1.2$ mm



CAT # 368, FACE 9

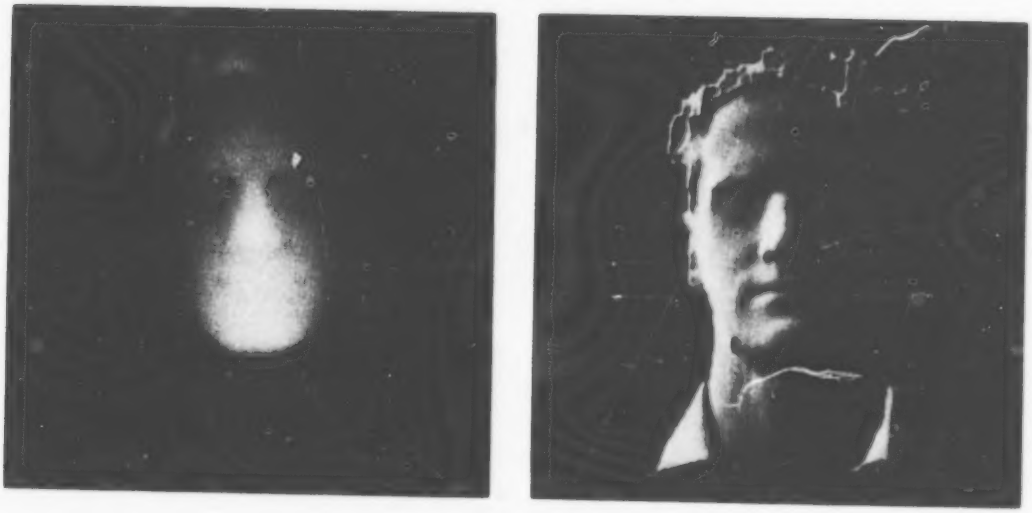
$\Delta x = \Delta y = 1.2$ mm

CAT # 419, FACE 10

$\Delta x = \Delta y = 1.2$ mm

CAT # 420, FACE 11

$\Delta x = \Delta y = 1.2$ mm



CAT # 417, FACE 12

$\Delta x = \Delta y = 1.2$ mm

CAT # 418, FACE 13

$\Delta x = \Delta y = 1.2$ mm

CAT # 415, FACE 14

$\Delta x = \Delta y = 1.2$ mm

CAT # 416, FACE 15

$\Delta x = \Delta y = 1.2$ mm

CAT # 399, FACE 16

$\Delta x = \Delta y = 1.2$ mm

CAT # 400, FACE 17

$\Delta x = \Delta y = 1.2$ mm

CAT # 397, FACE 18

$\Delta x = \Delta y = 1.2$ mm

CAT # 398, FACE 19

$\Delta x = \Delta y = 1.2$ mm

CAT # 395, FACE 20

$\Delta x = \Delta y = 1.2$ mm

CAT # 396, FACE 21

$\Delta x = \Delta y = 1.2$ mm

CAT # 383, FACE 22

$\Delta x = \Delta y = 1.2$ mm

CAT # 384, FACE 23

$\Delta x = \Delta y = 1.2$ mm

CAT # 379, FACE 24

$\Delta x = \Delta y = 1.2$ mm

CAT # 380, FACE 25

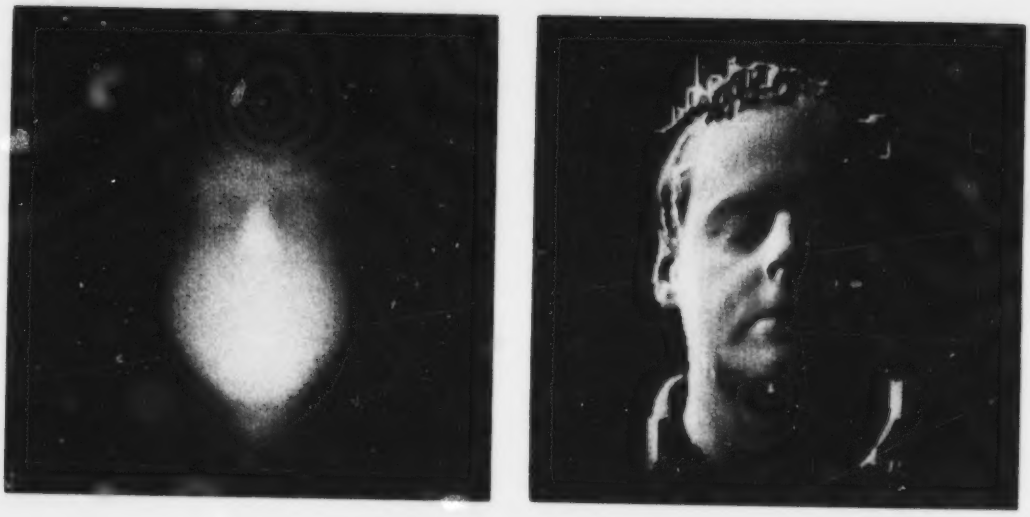
$\Delta x = \Delta y = 1.2$ mm

CAT # 376, FACE 26

$\Delta x = \Delta y = 1.2$ mm

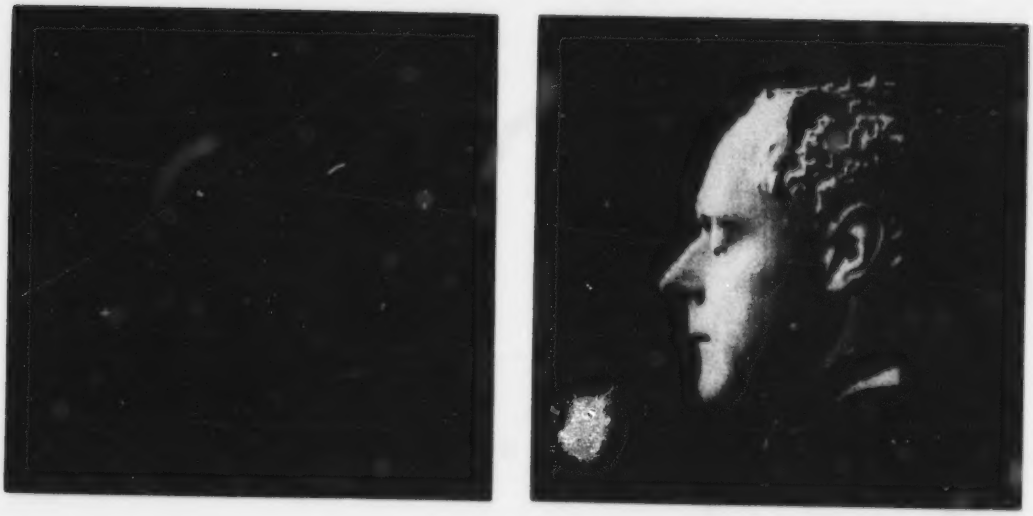
CAT # 377, FACE 27

$\Delta x = \Delta y = 1.2$ mm



CAT # 372, FACE 28

$\Delta x = \Delta y = 1.2$ mm



CAT # 373, FACE 29

$\Delta x = \Delta y = 1.2$ mm

CAT # 409, FACE 30

$\Delta x = \Delta y = 1.2$ mm

CAT # 407, FACE 31

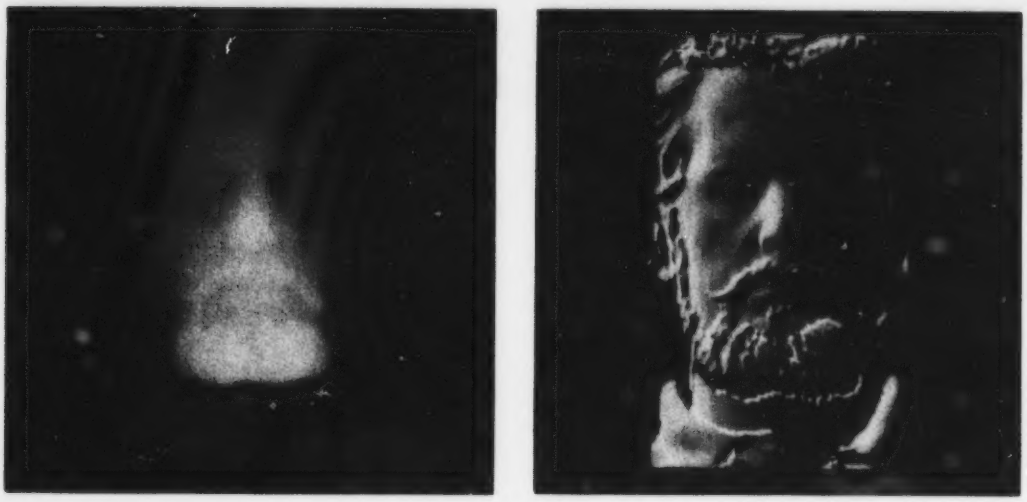
$\Delta x = \Delta y = 1.2$ mm

CAT # 392, FACE 32

$\Delta x = \Delta y = 1.2$ mm

CAT # 374, FACE 33

$\Delta x = \Delta y = 1.2$ mm



CAT # 366, FACE 34

$\Delta x = \Delta y = 1.2$ mm

CAT # 370, FACE 35

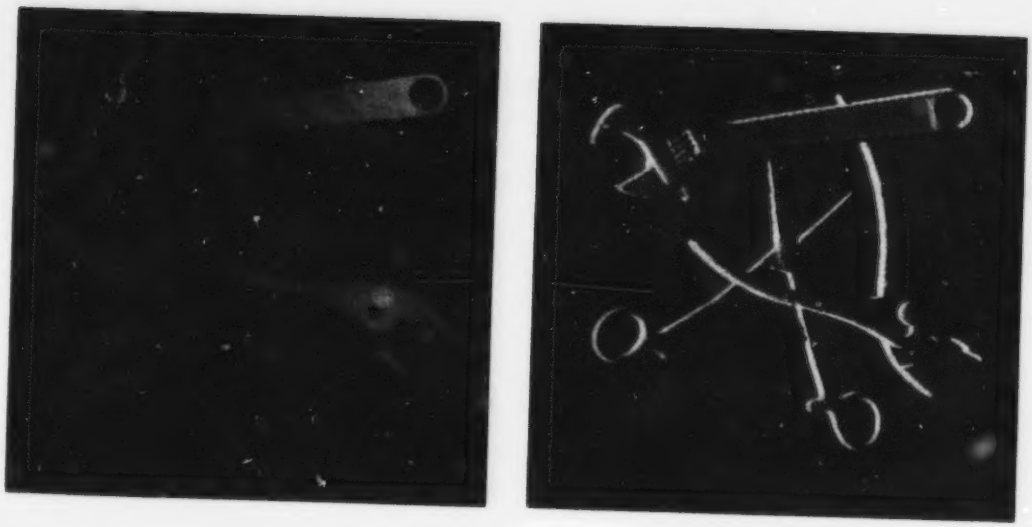
$\Delta x = \Delta y = 1.2$ mm

CAT # 381, FACE 36

$\Delta x = \Delta y = 1.2$ mm

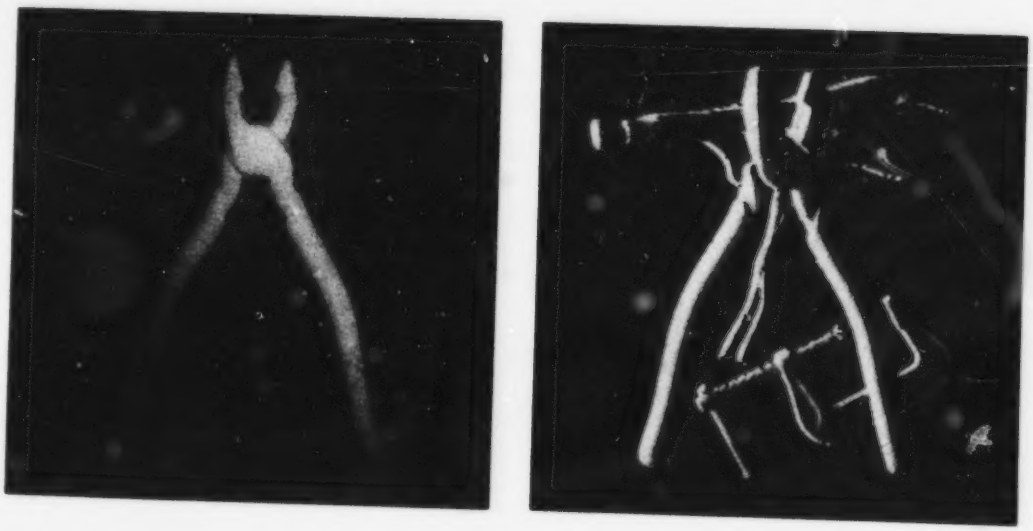
CAT # 412, FACE 37

$\Delta x = \Delta y = 1.2$ mm



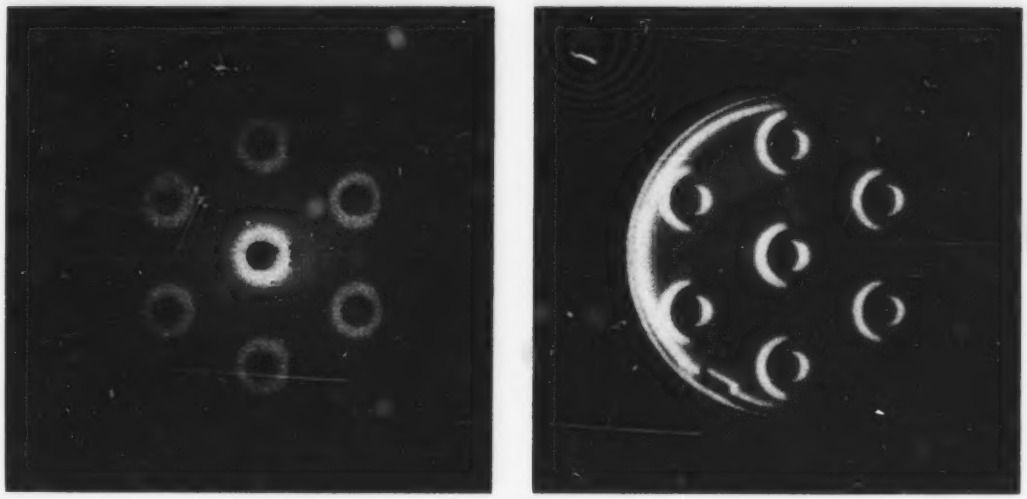
CAT # 075, TOOL 13

$\Delta x = \Delta y = 0.9$ mm



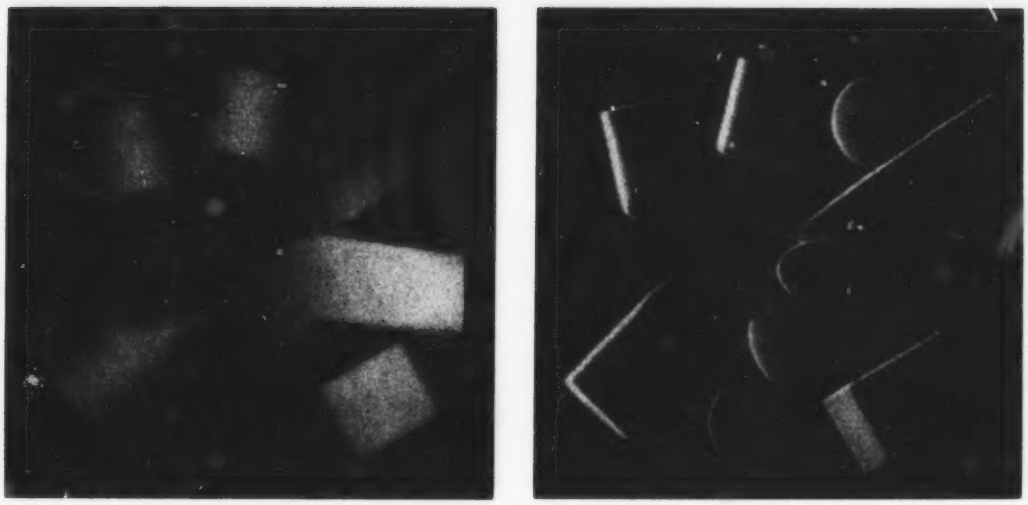
CAT # 076, TOOL 14

$\Delta x = \Delta y = 0.9$ mm



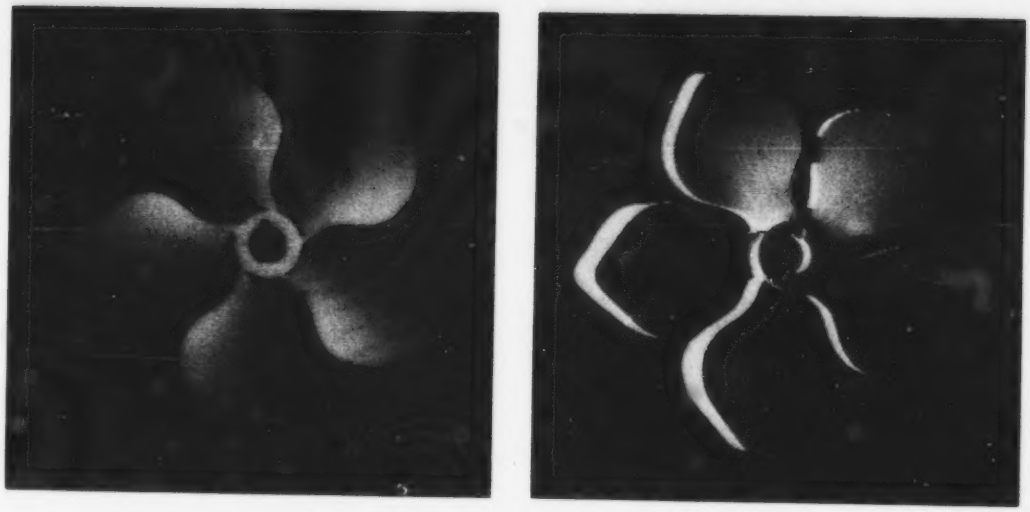
CAT # 260, MECA 9

$\Delta x = \Delta y = 0.5$ mm



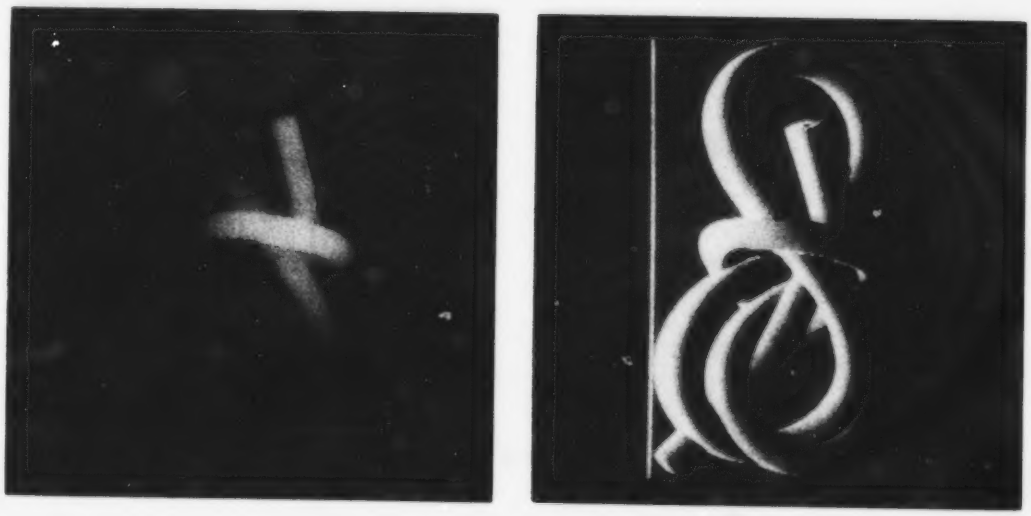
CAT # 105, BLOC 16

$\Delta x = \Delta y = 0.5$ mm



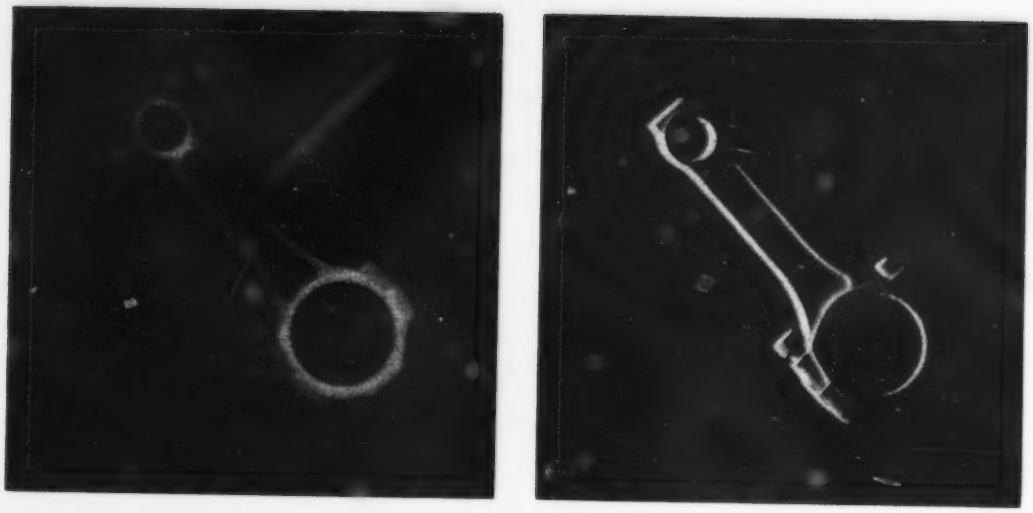
CAT # 111, HELI 1

$\Delta x = \Delta y = 0.8$ mm



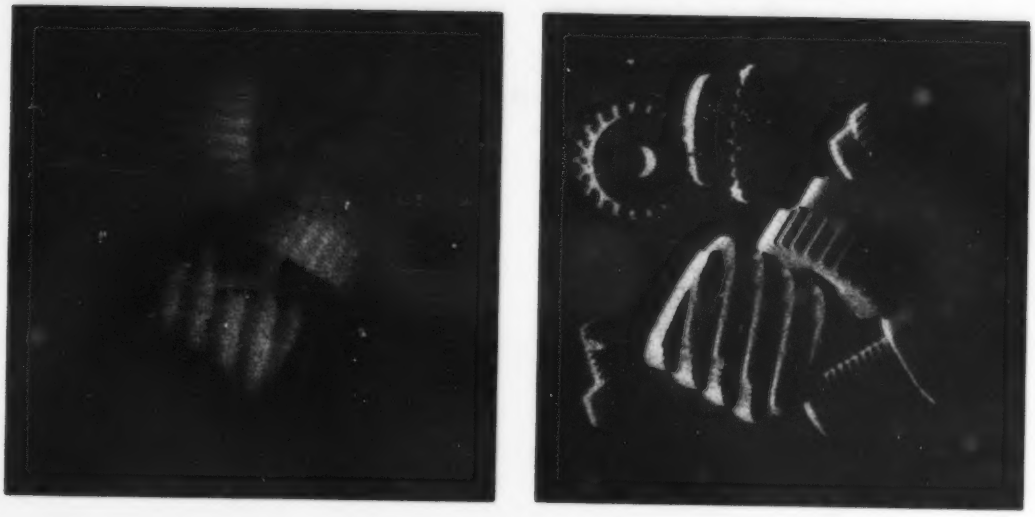
CAT # 120, TUBE 1

$\Delta x = \Delta y = 1.5$ mm



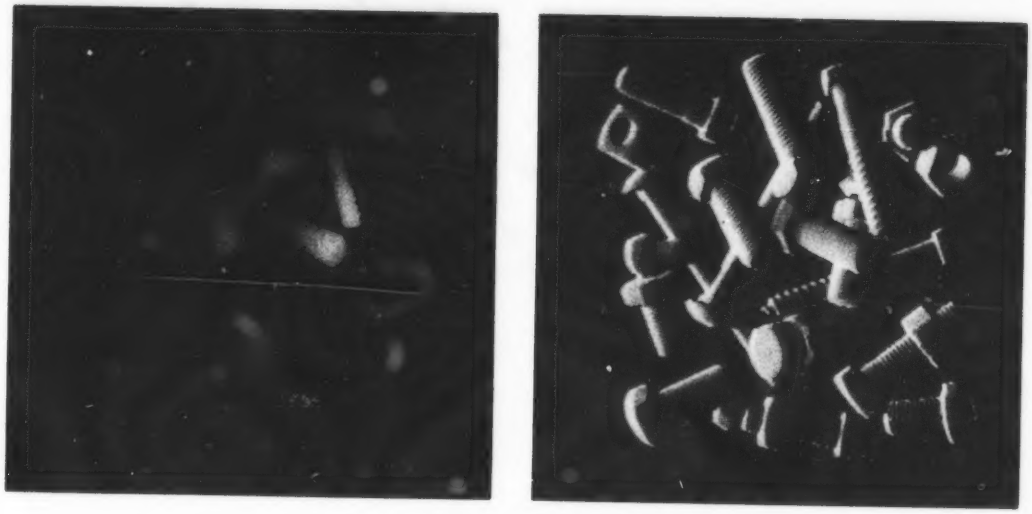
CAT # 272, MECA 7

$\Delta x = \Delta y = 0.9$ mm



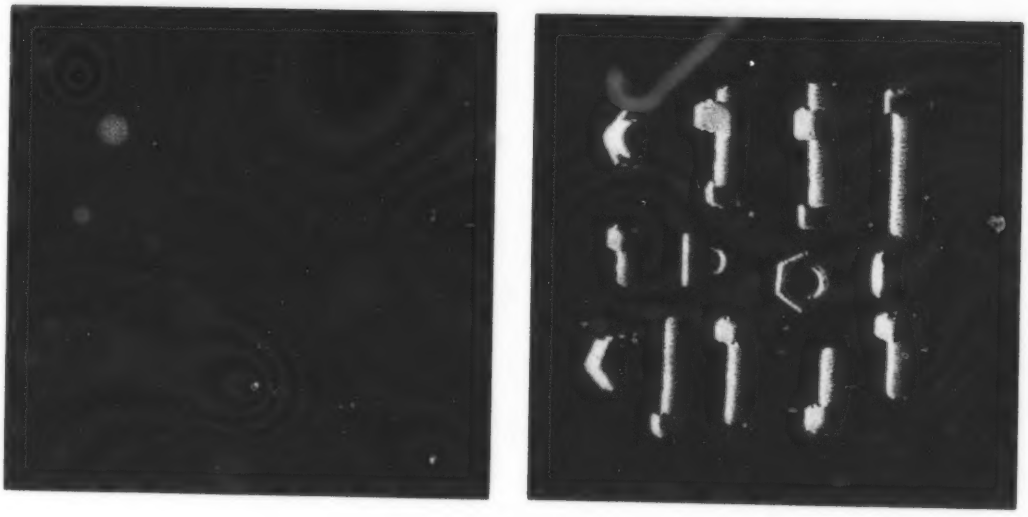
CAT # 058, BOLT 11

$\Delta x = \Delta y = 0.5$ mm



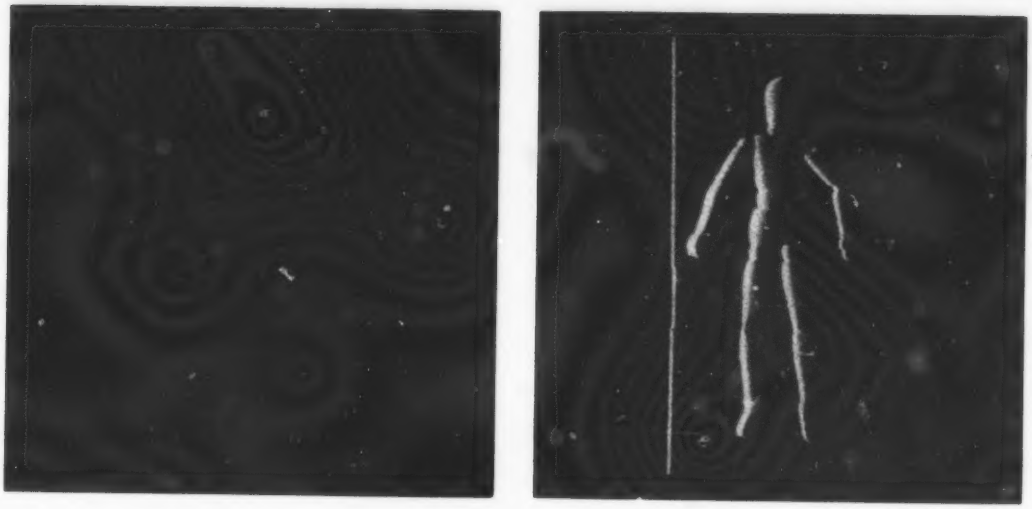
CAT # 060, BOLT 10

$\Delta x = \Delta y = 0.9$ mm



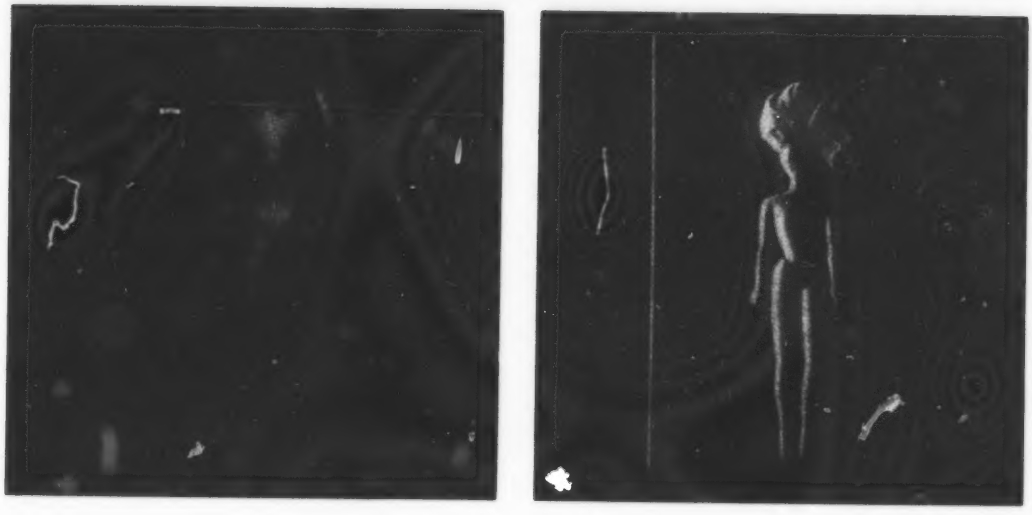
CAT # 045, BOLT 12

$\Delta x = \Delta y = 0.9$ mm



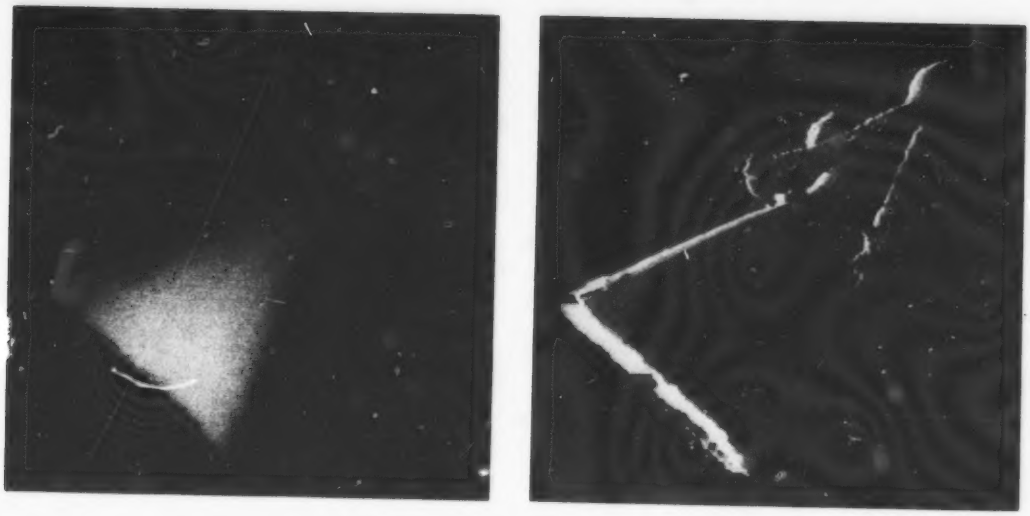
CAT # 422, DOLL 1

$\Delta x = \Delta y = 2.0$ mm



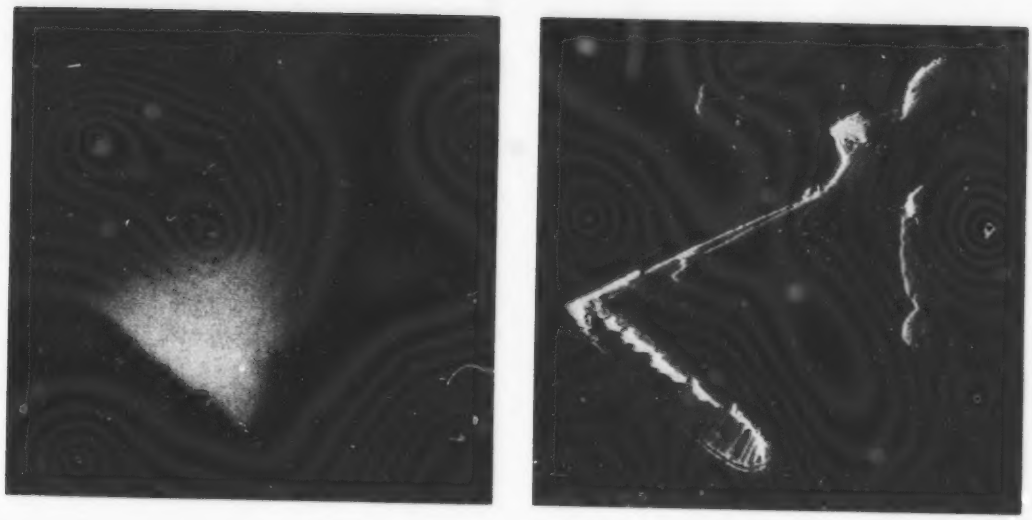
CAT # 172, DOLL 2

$\Delta x = \Delta y = 1.5$ mm



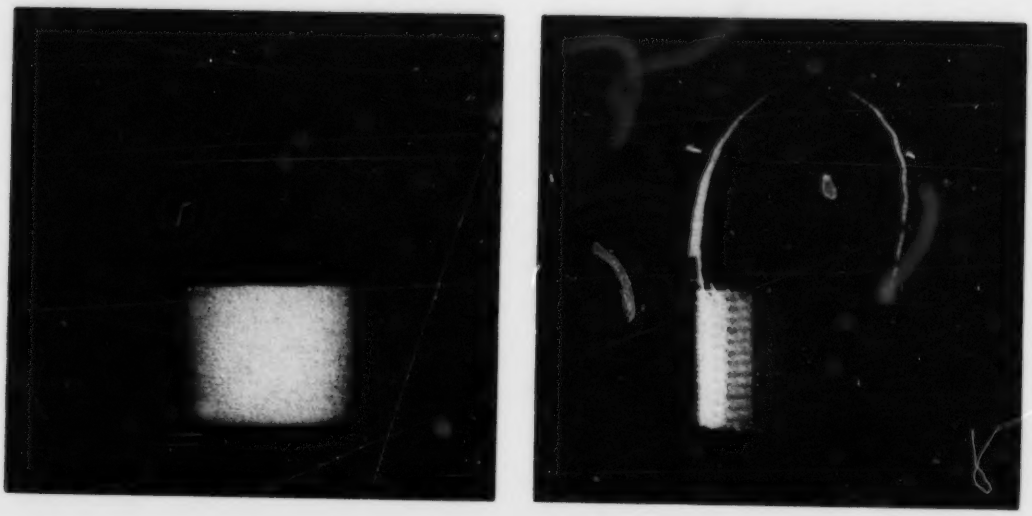
CAT # 141, DOLL 3

$\Delta x = \Delta y = 0.9$ mm



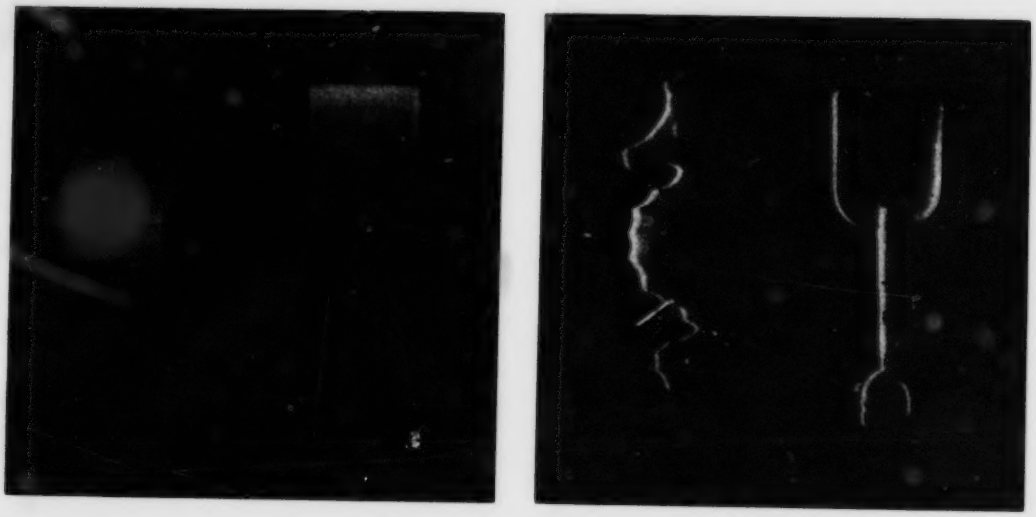
CAT # 140, DOLL 4

$\Delta x = \Delta y = 0.9$ mm



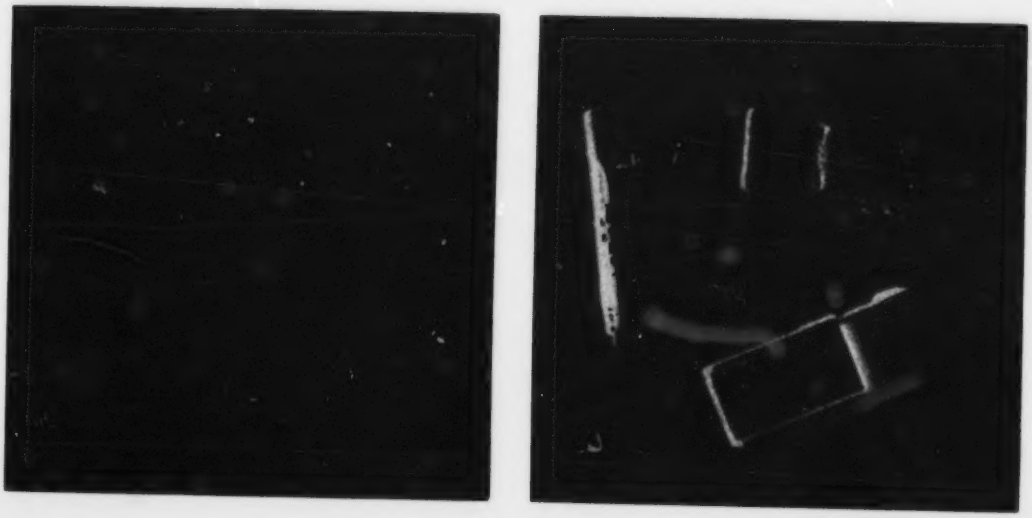
CAT # 148, TOY 1

$\Delta x = \Delta y = 0.9$ mm



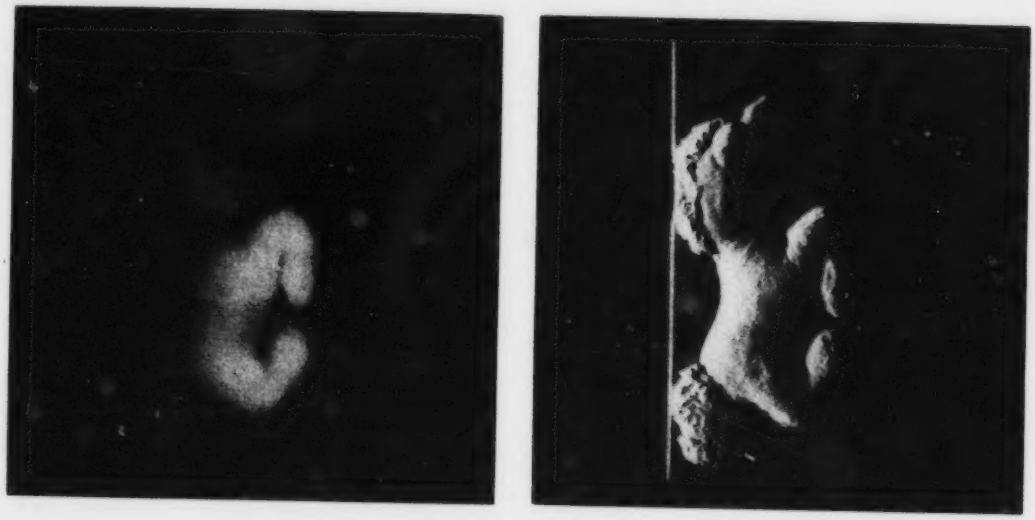
CAT # 146, TOY 2

$\Delta x = \Delta y = 0.9$ mm



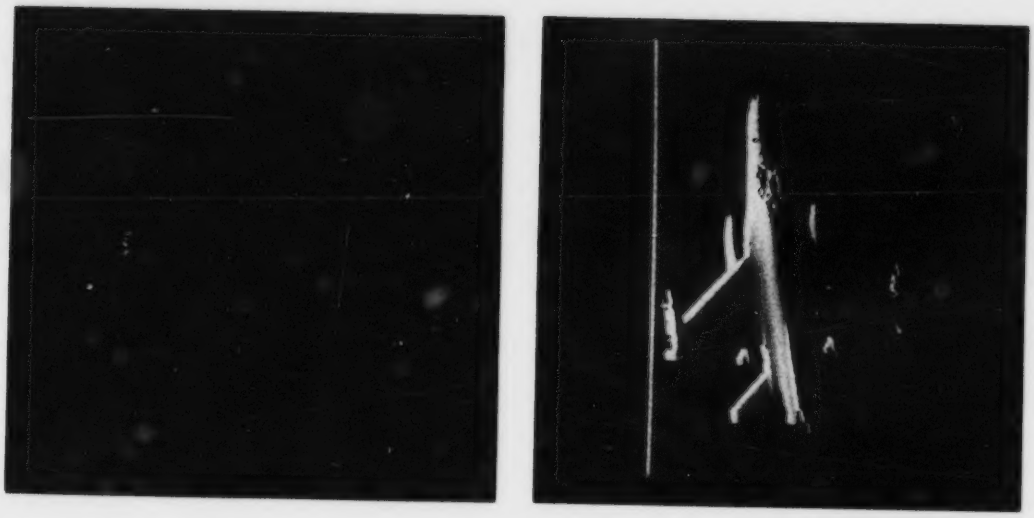
CAT # 164, TOY 3

$\Delta x = \Delta y = 0.5$ mm



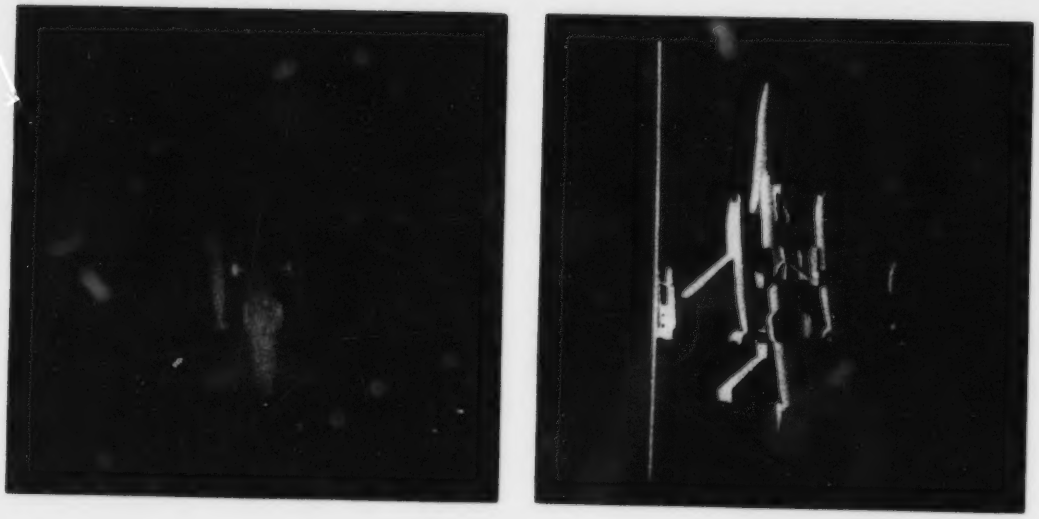
CAT # 139, TOY 4

$\Delta x = \Delta y = 2.0$ mm



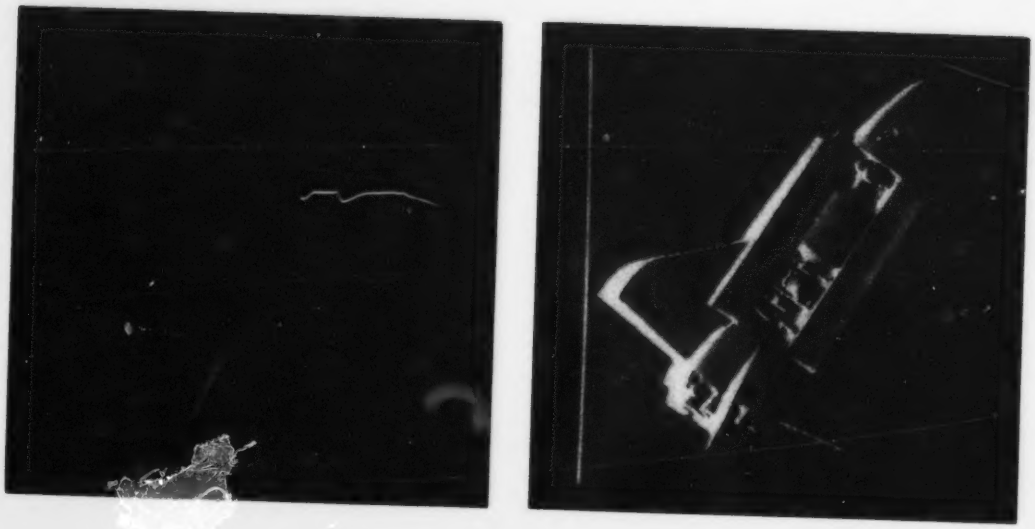
CAT # 124, JET 1

$\Delta x = \Delta y = 1.5$ mm



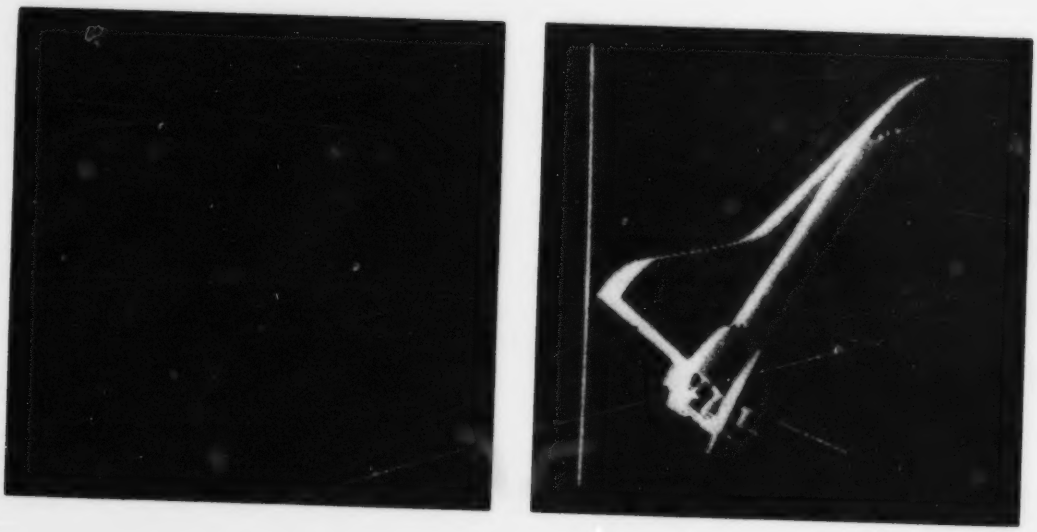
CAT # 125, JET 2

$\Delta x = \Delta y = 1.5$ mm



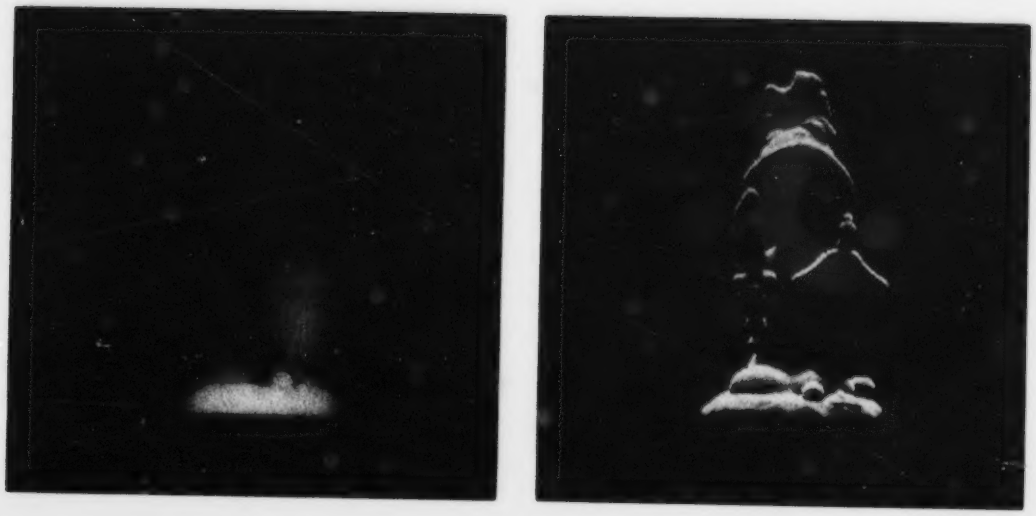
CAT # 122, JET 3

$\Delta x = \Delta y = 1.0$ mm



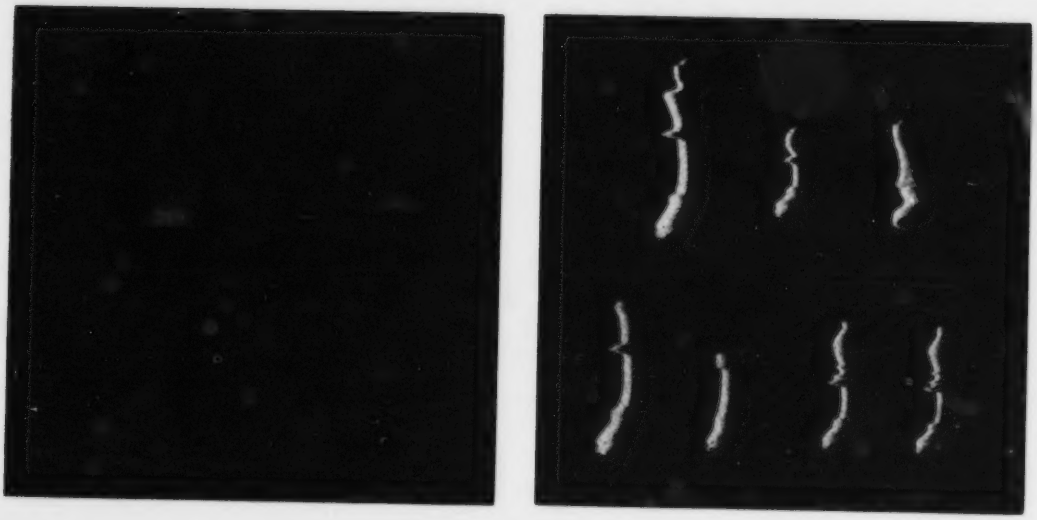
CAT # 121, JET 4

$\Delta x = \Delta y = 1.0$ mm



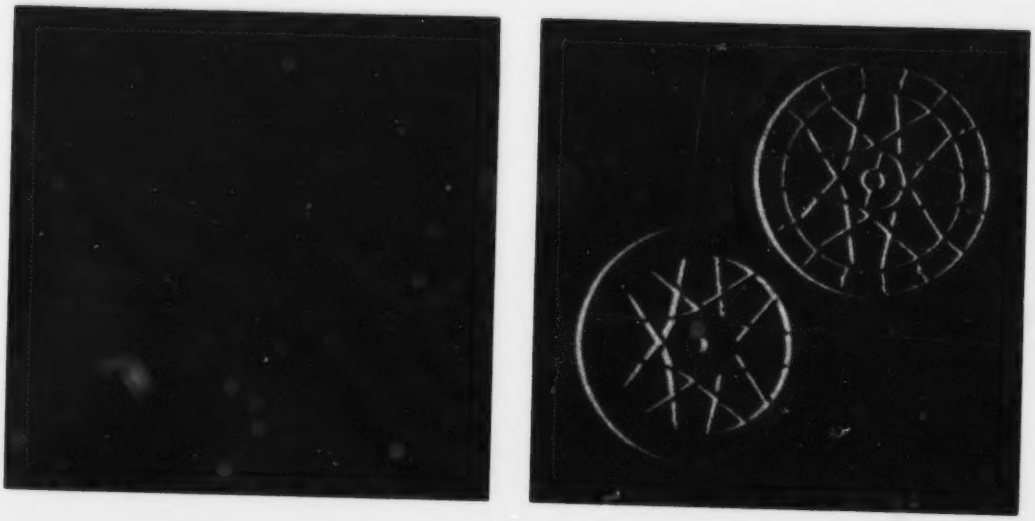
CAT # 285, TOY 5

$\Delta x = \Delta y = 0.75$mm



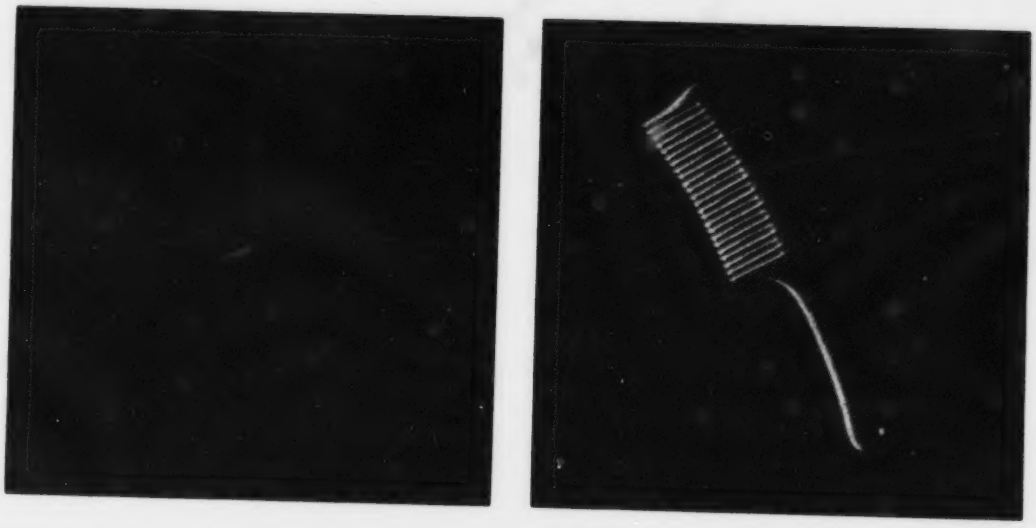
CAT # 157, TOY 6

$\Delta x = \Delta y = 0.9$ mm



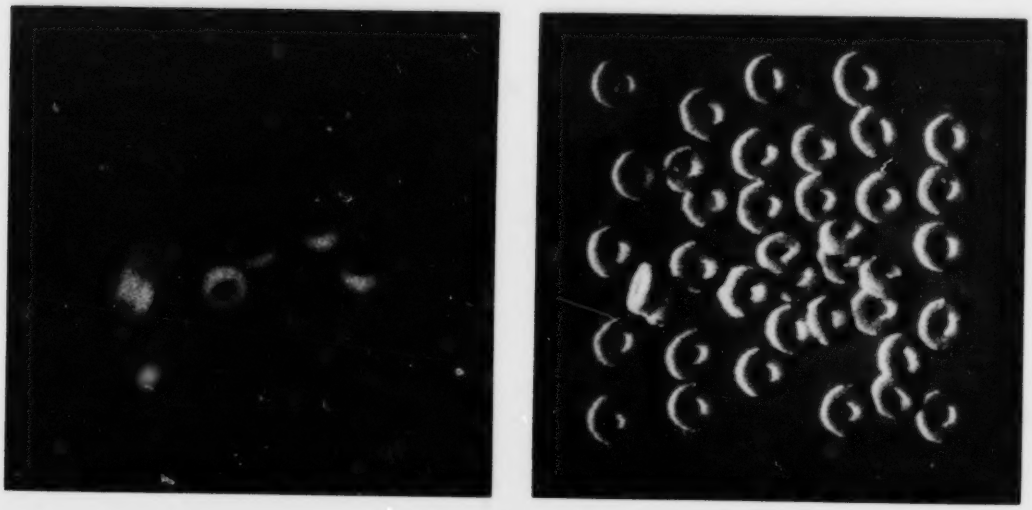
CAT # 135, TOY 7

$\Delta x = \Delta y = 0.9$ mm



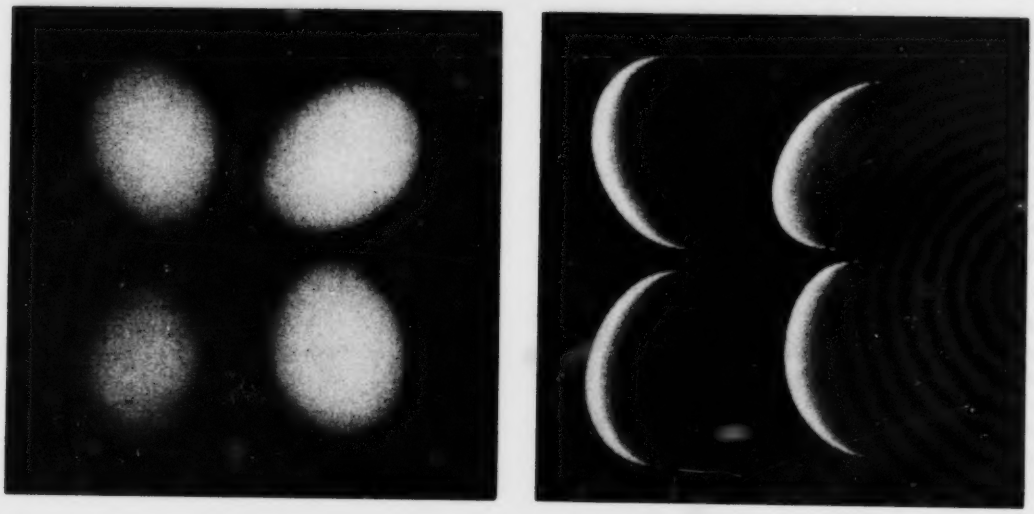
CAT # 190, TOY 8

$\Delta x = \Delta y = 0.9$ mm



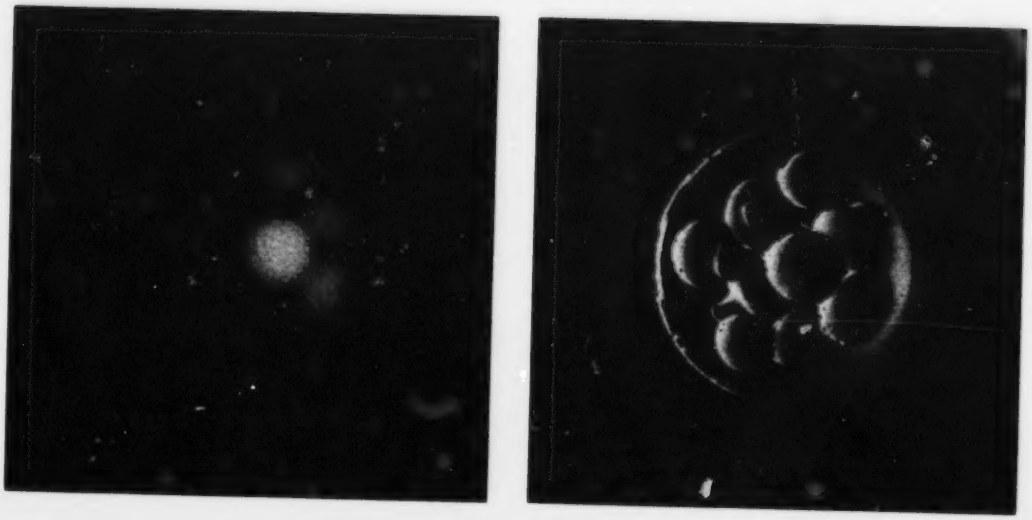
CAT # 226, CHER 1

$\Delta x = \Delta y = 0.5$ mm



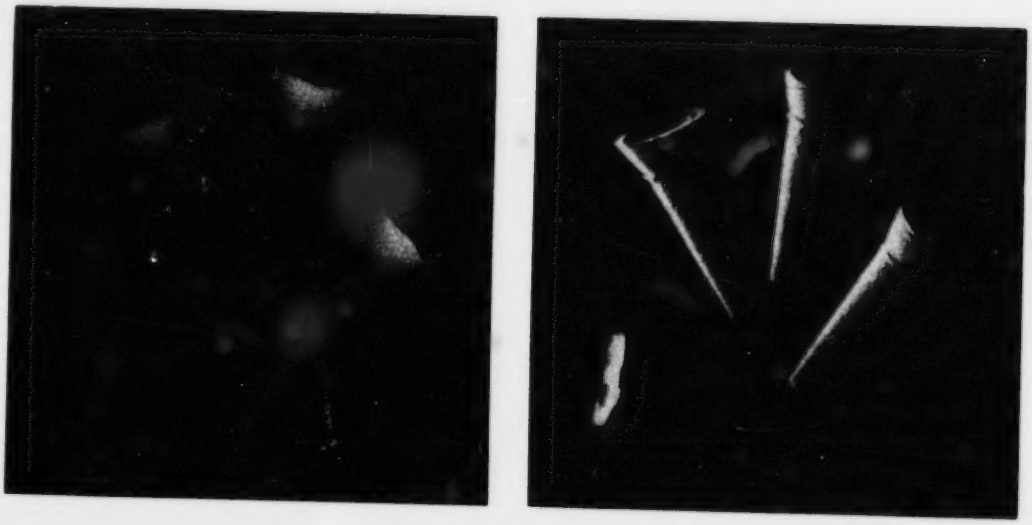
CAT # 223, EGG 1

$\Delta x = \Delta y = 0.5$ mm



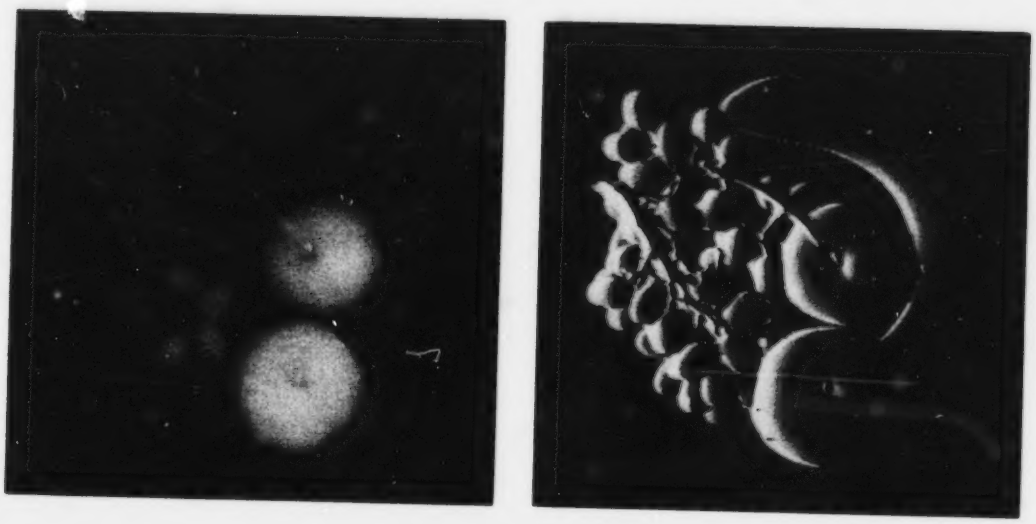
CAT # 188, MUSH 1

$\Delta x = \Delta y = 0.9$ mm



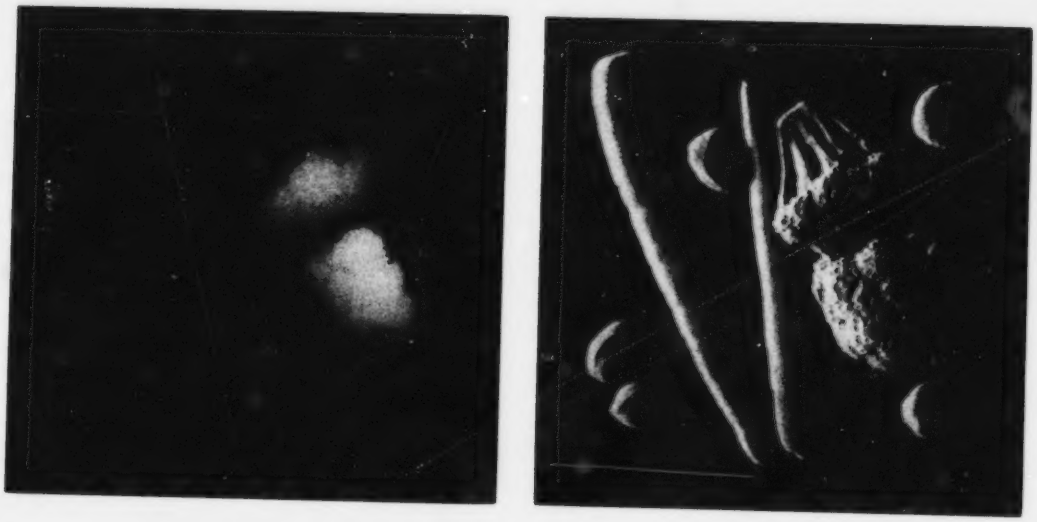
CAT # 217, CONE 1

$\Delta x = \Delta y = 0.9$ mm



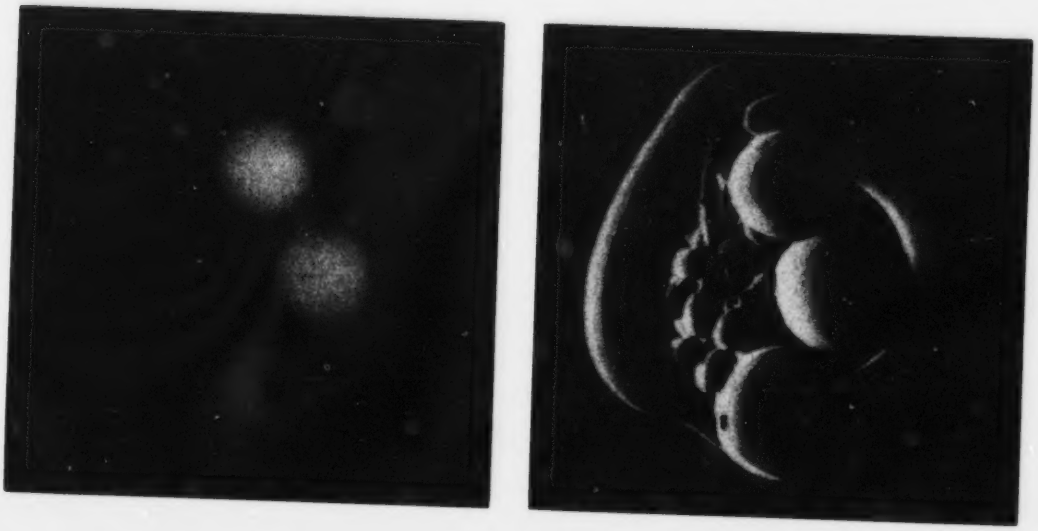
CAT # 203, FRUI 1

$\Delta x = \Delta y = 0.9$ mm



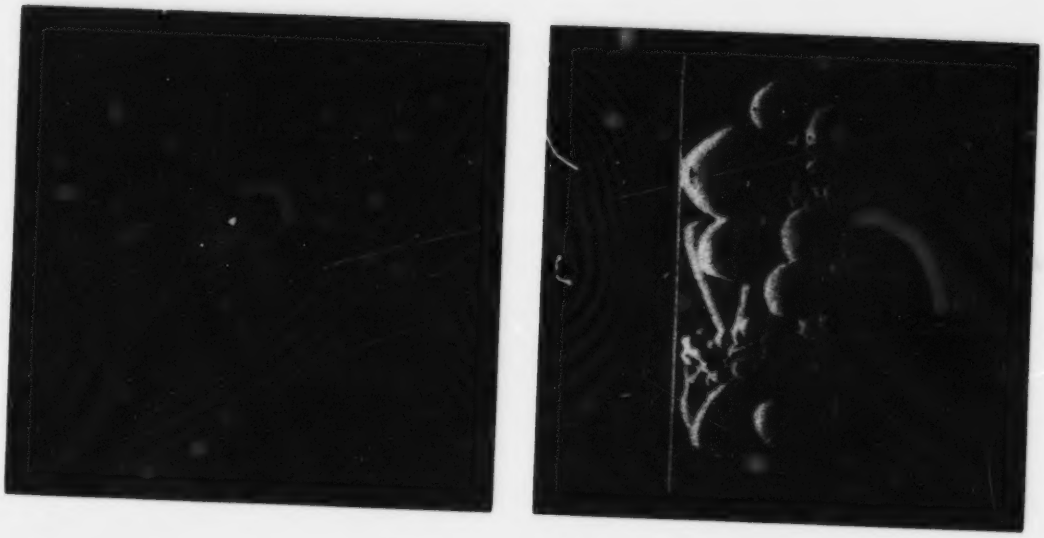
CAT # 212, VEG 1

$\Delta x = \Delta y = 0.9$ mm



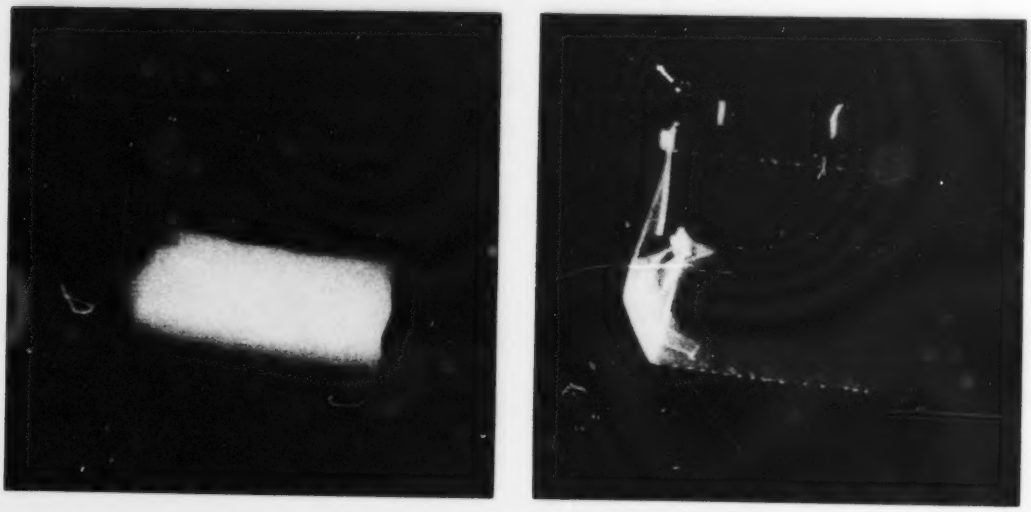
CAT # 209, FRUI 2

$\Delta x = \Delta y = 0.9$ mm



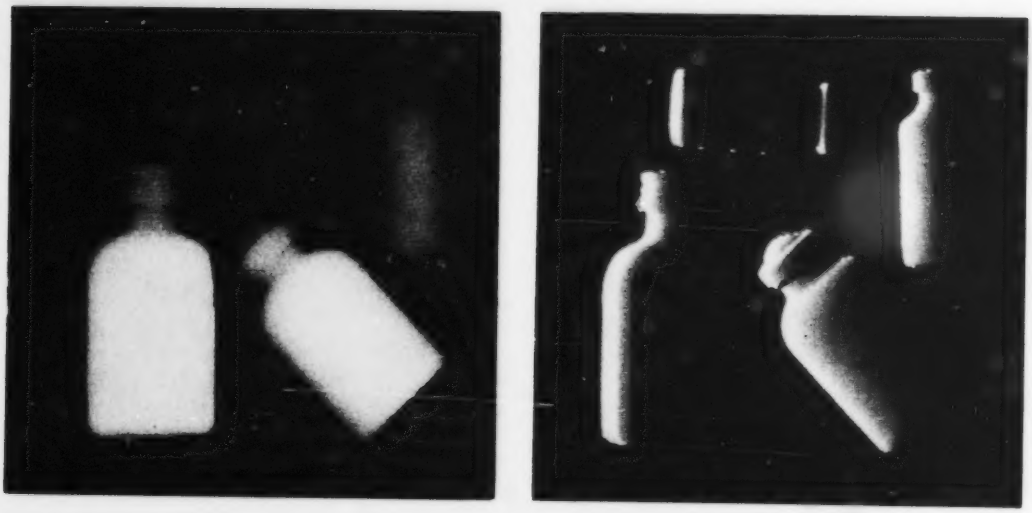
CAT # 213, FRUI 3

$\Delta x = \Delta y = 2.0$ mm



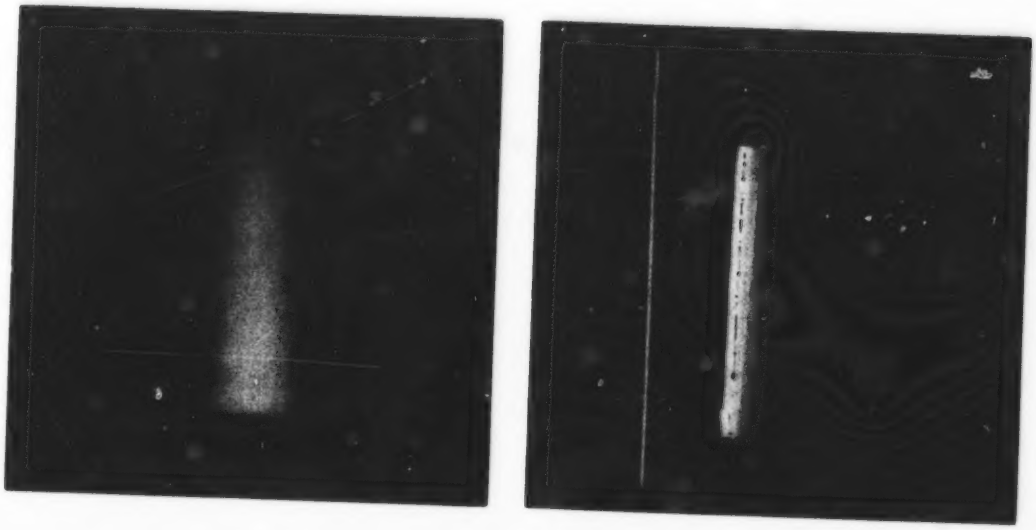
CAT # 154, BAG 1

$\Delta x = \Delta y = 0.9$ mm



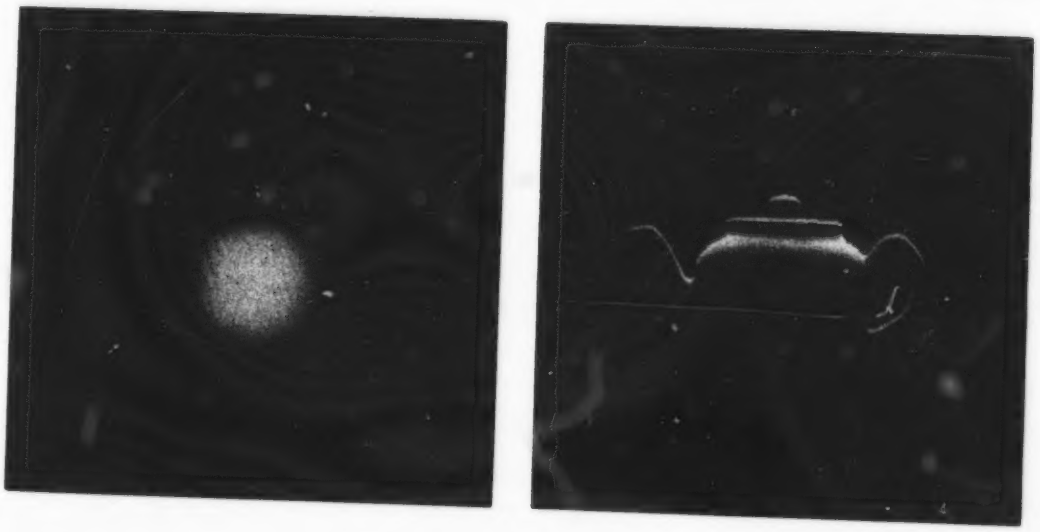
CAT # 262, MECA 12

$\Delta x = \Delta y = 0.5$ mm



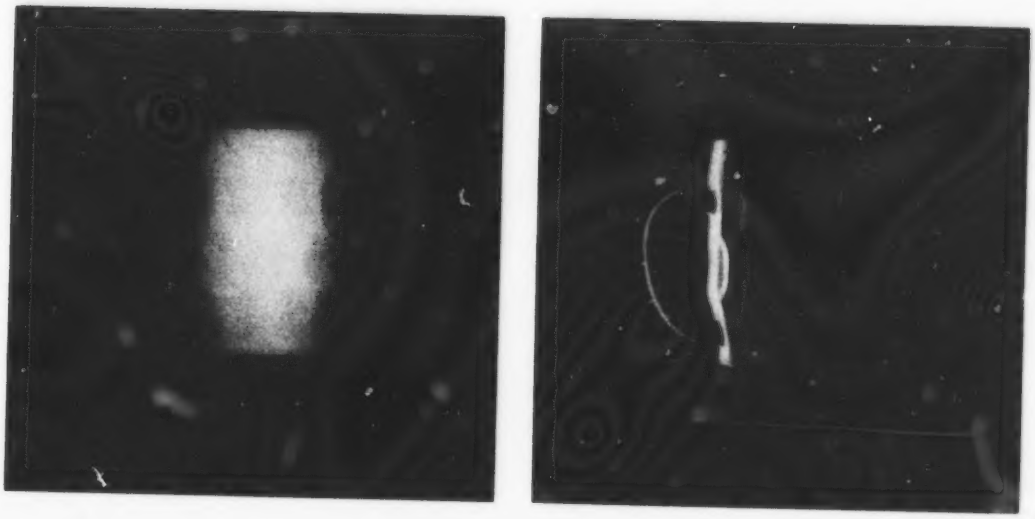
CAT # 284, THER 1

$\Delta x = \Delta y = 1.5$ mm



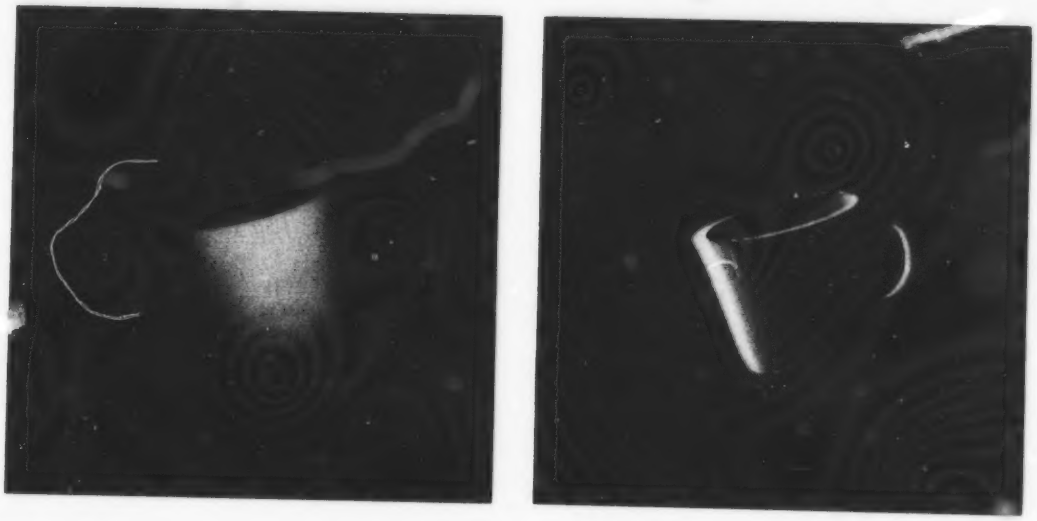
CAT # 309, POT 1

$\Delta x = \Delta y = 1.5$ mm



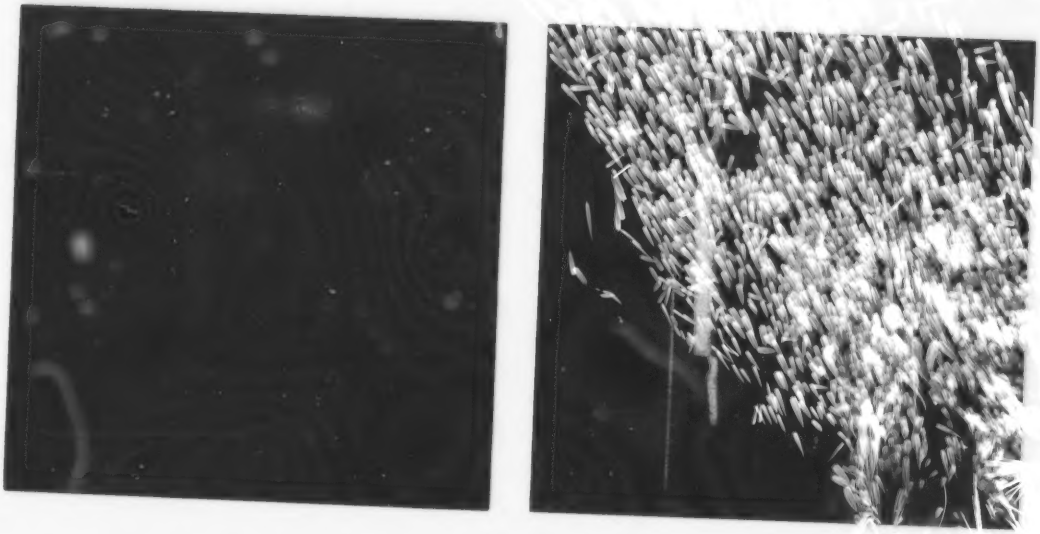
CAT # 251, MUG 1

$\Delta x = \Delta y = 0.9$ mm



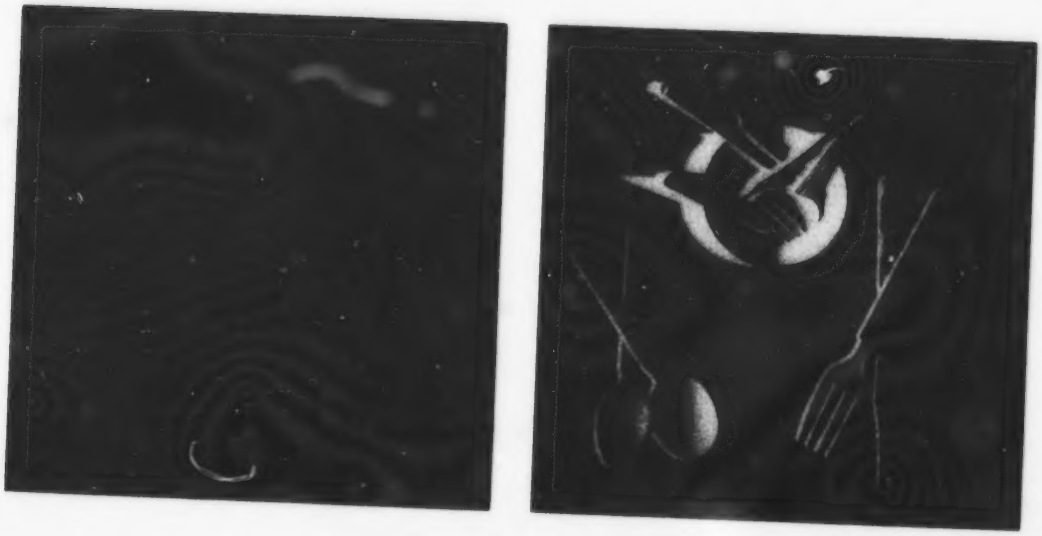
CAT # 268, CUP 3

$\Delta x = \Delta y = 0.9$ mm



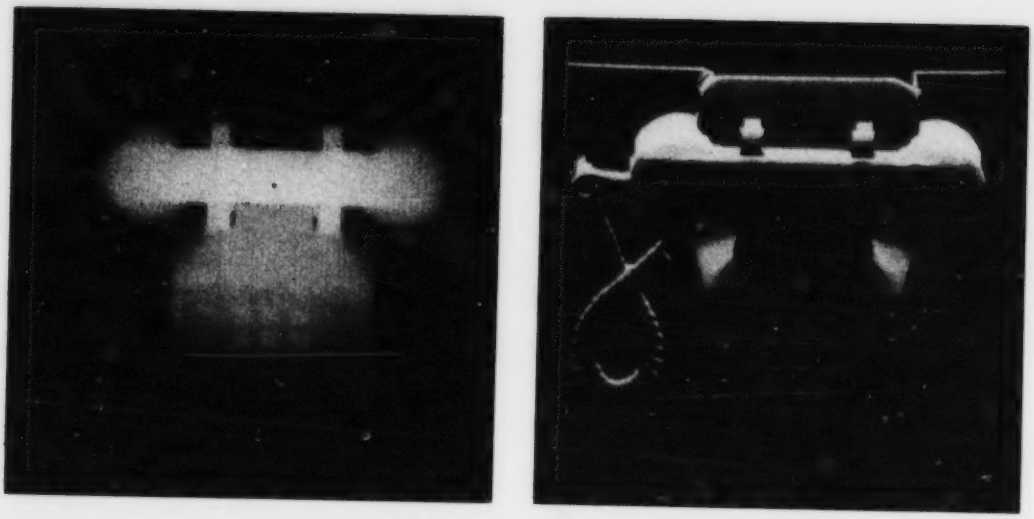
CAT # 214, UTEN 17

$\Delta x = \Delta y = 2.0$ mm



CAT # 022, UTEN 4

$\Delta x = \Delta y = 0.9$ mm

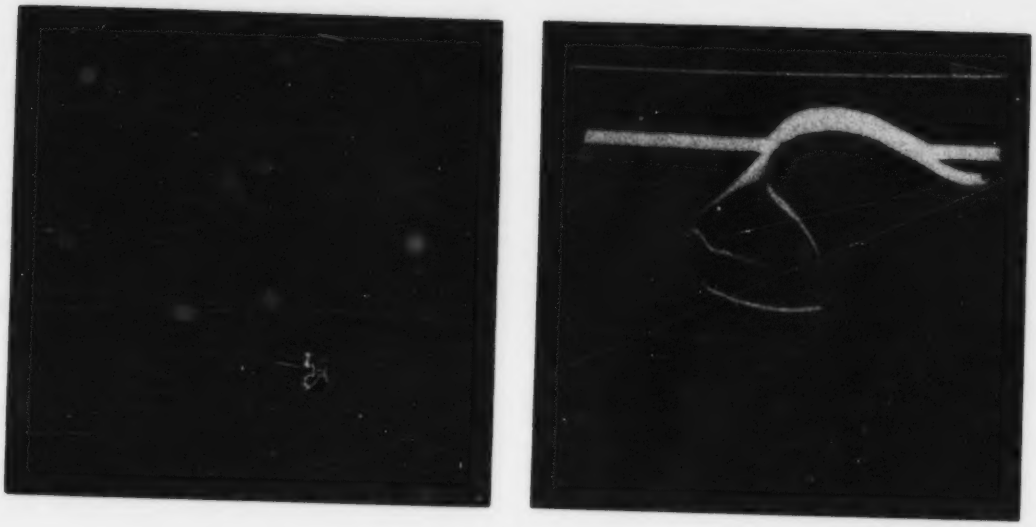


CAT # 028, TEL 1

$\Delta x = \Delta y = 1.0$ mm

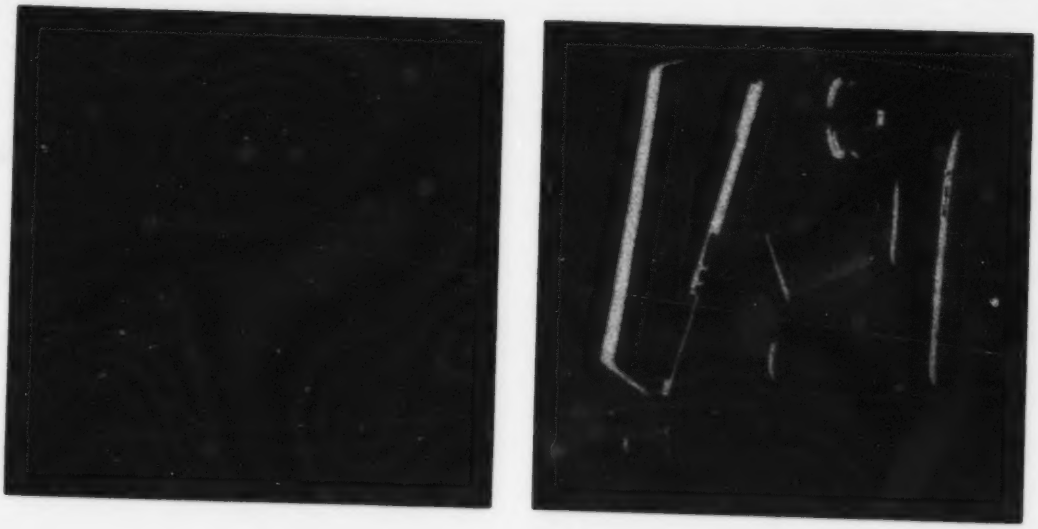
CAT # 302, SHAR 1

$\Delta x = \Delta y = 0.75$ mm



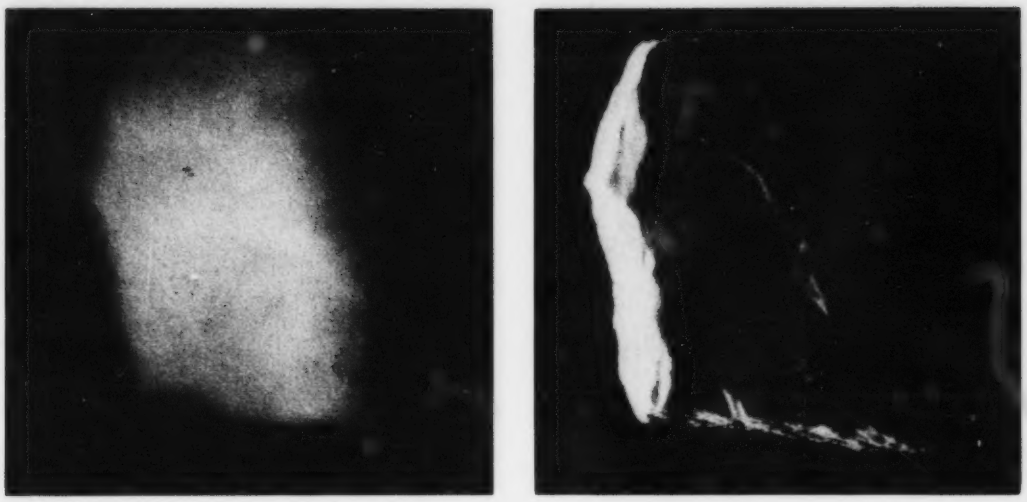
CAT # 042, KLEE 1

$\Delta x = \Delta y = 1.0$ mm



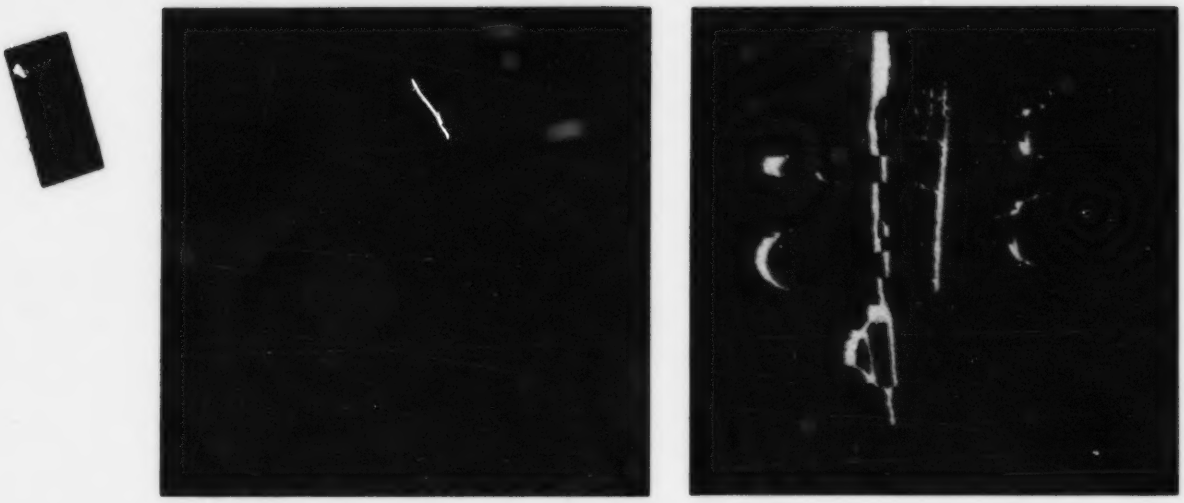
CAT # 043, PEN 1

$\Delta x = \Delta y = 0.9$ mm



CAT # 355, ROCK 1

$\Delta x = \Delta y = 0.5$ mm

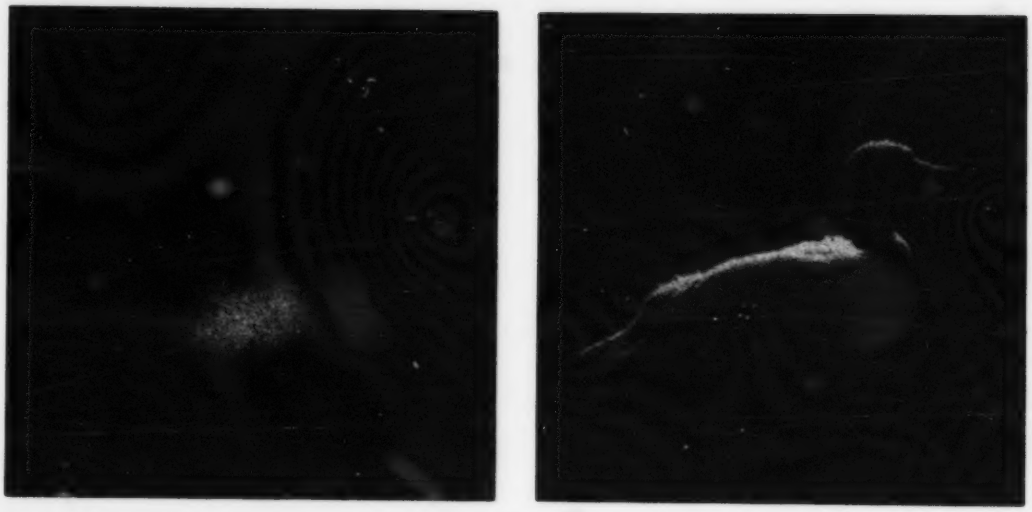


CAT # 128, MUSI 1

$\Delta x = \Delta y = 0.5$ mm

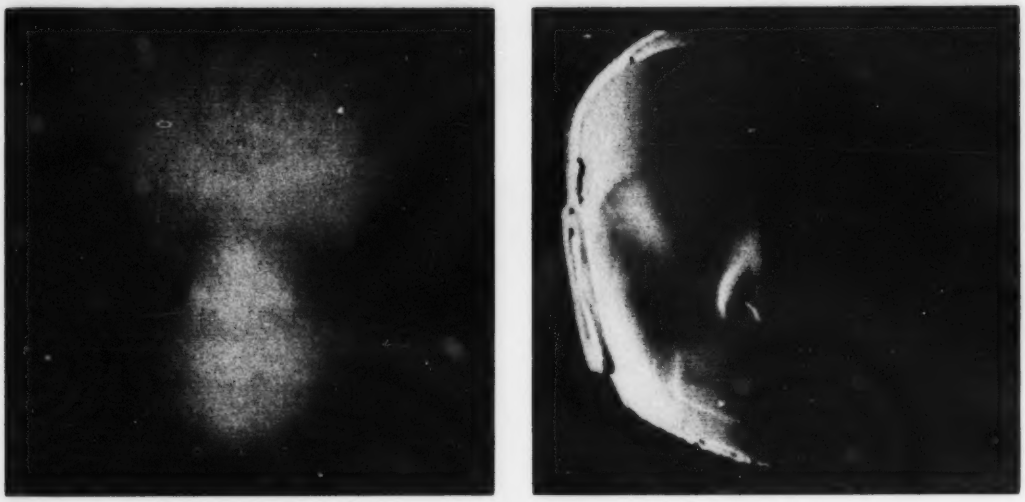
CAT # 389, FACE 38

$\Delta x = \Delta y = 1.2$ mm



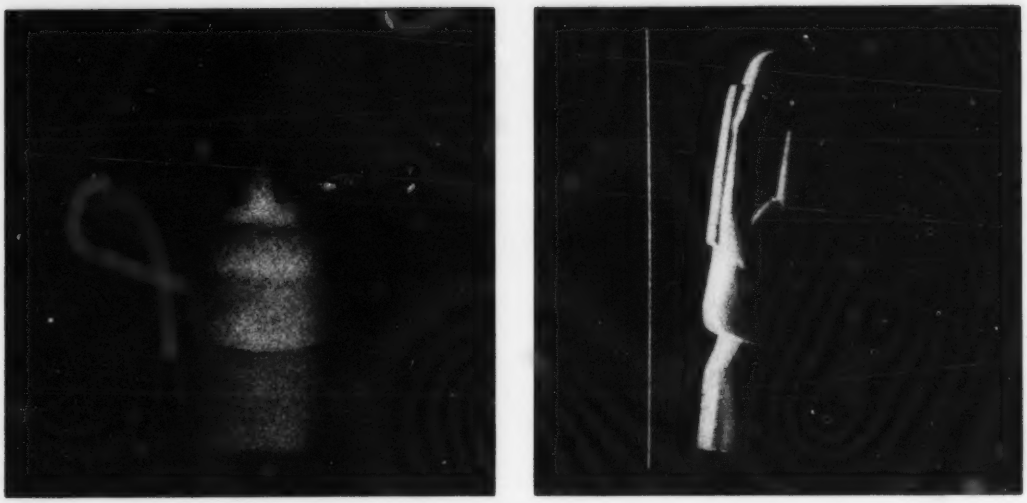
CAT # 364, BIRD 1

$\Delta x = \Delta y = 1.5$ mm



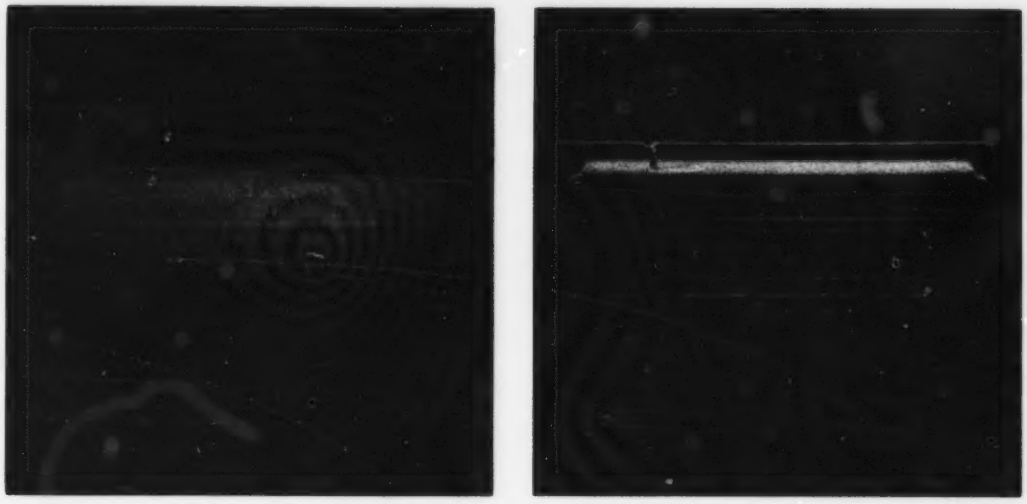
CAT # 001, MASK 1

$\Delta x = \Delta y = 0.9$ mm



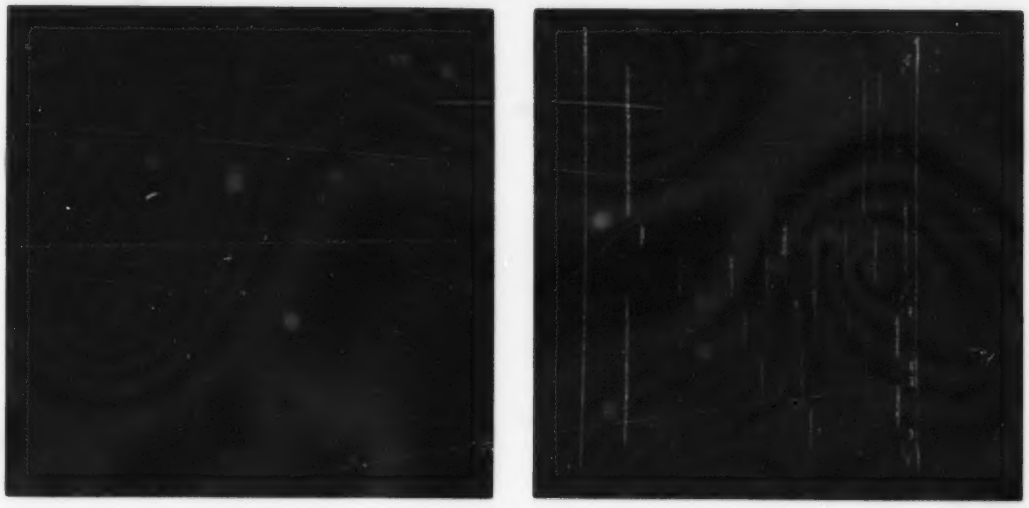
CAT # 155, STAT 1

$\Delta x = \Delta y = 1.5$ mm



CAT # 169, KEY 1

$\Delta x = \Delta y = 2.0$ mm



CAT # 133, PCB 3

$\Delta x = \Delta y = 1.0$ mm

CAT # 144, SHOE 1

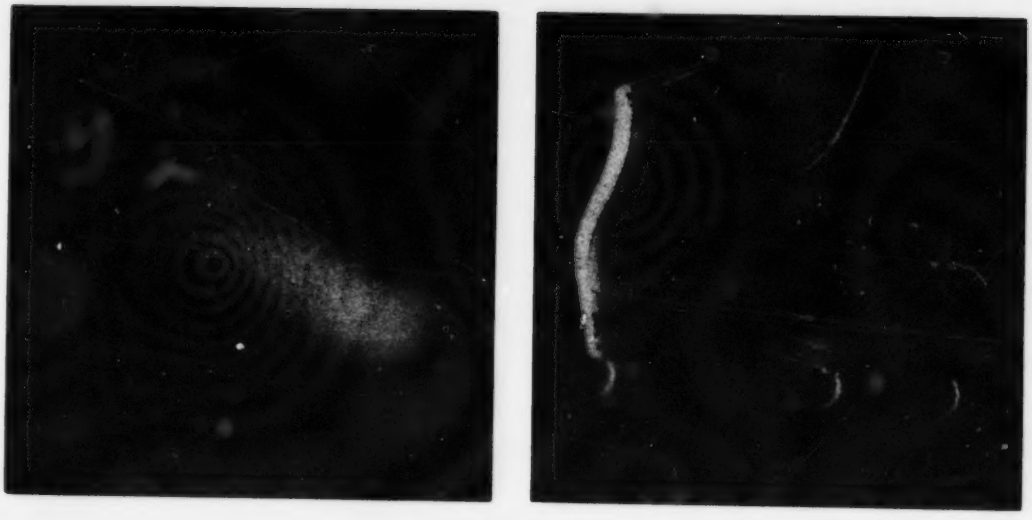
$\Delta x = \Delta y = 0.9$ mm

CAT # 145, SHOE 2

$\Delta x = \Delta y = 0.9$ mm

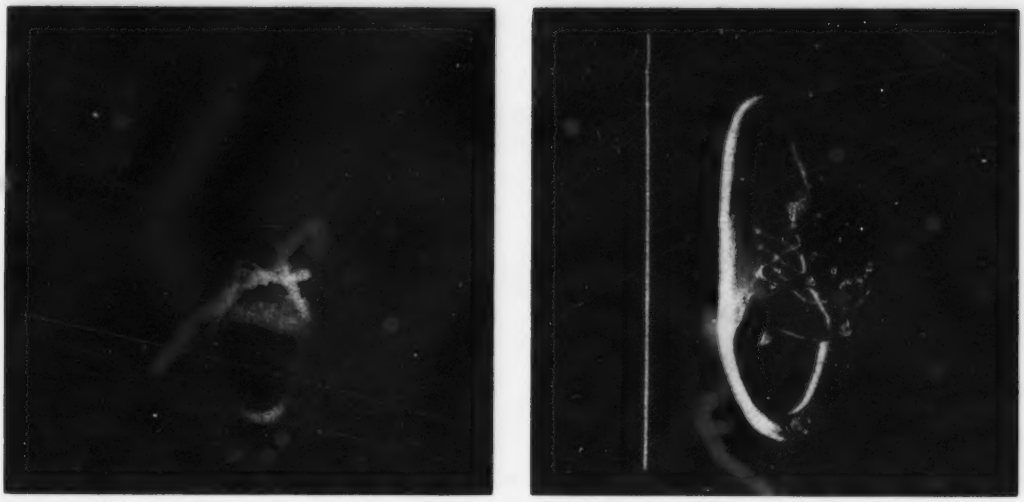
CAT # 136, SHOE 3

$\Delta x = \Delta y = 0.9$ mm



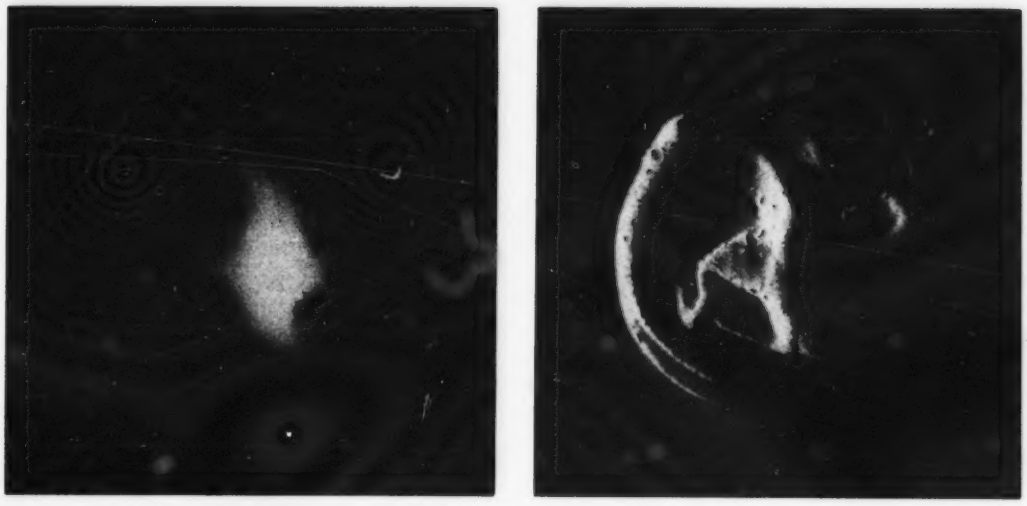
CAT # 138, SHOE 4

$\Delta x = \Delta y = 0.9$ mm



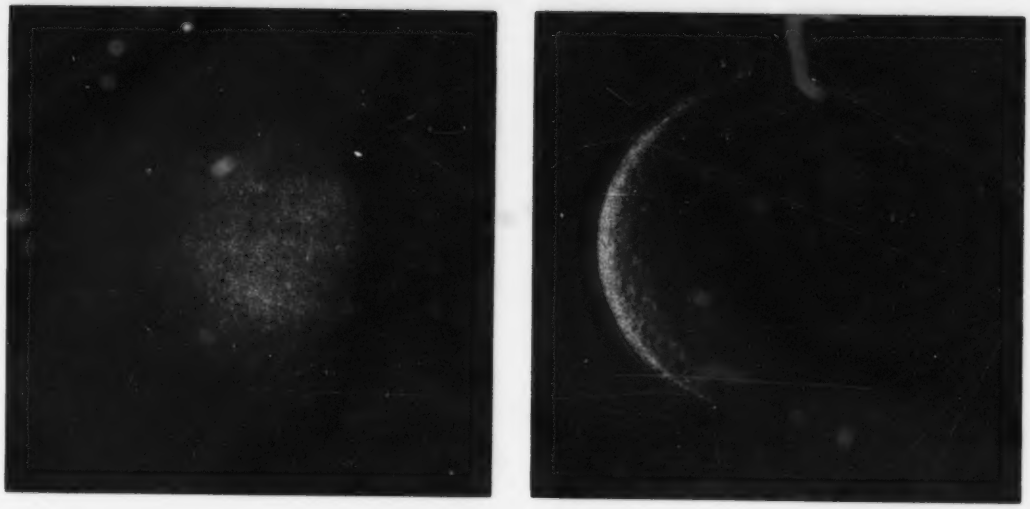
CAT # 266, SHOE 5

$\Delta x = \Delta y = 1.5$ mm



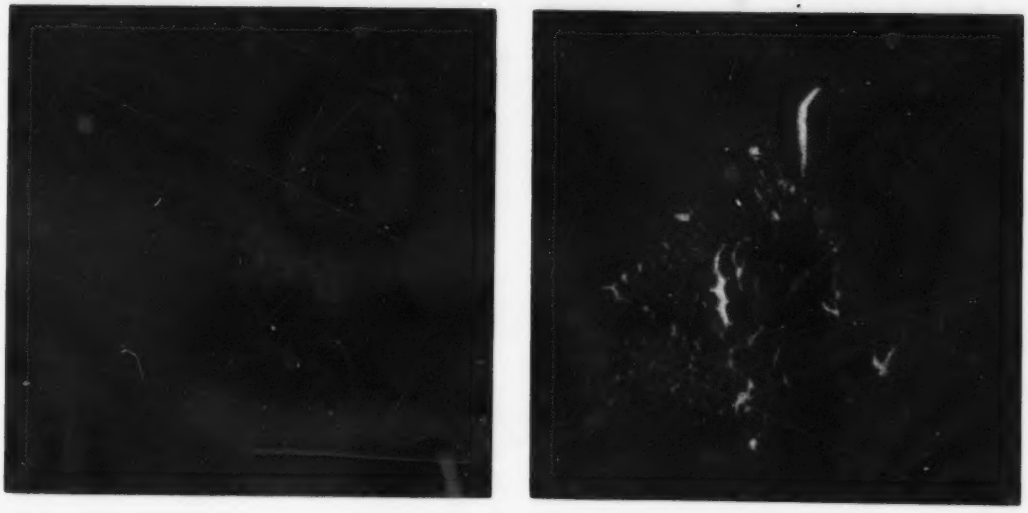
CAT # 134, HAT 1

$\Delta x = \Delta y = 0.9$ mm



CAT # 182, MOLD 1

$\Delta x = \Delta y = 0.5$ mm



CAT # 160, MOLD 2

$\Delta x = \Delta y = 0.5$ mm

CAT # 184, 10 RUB

$\Delta x = \Delta y = 0.5$ mm

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